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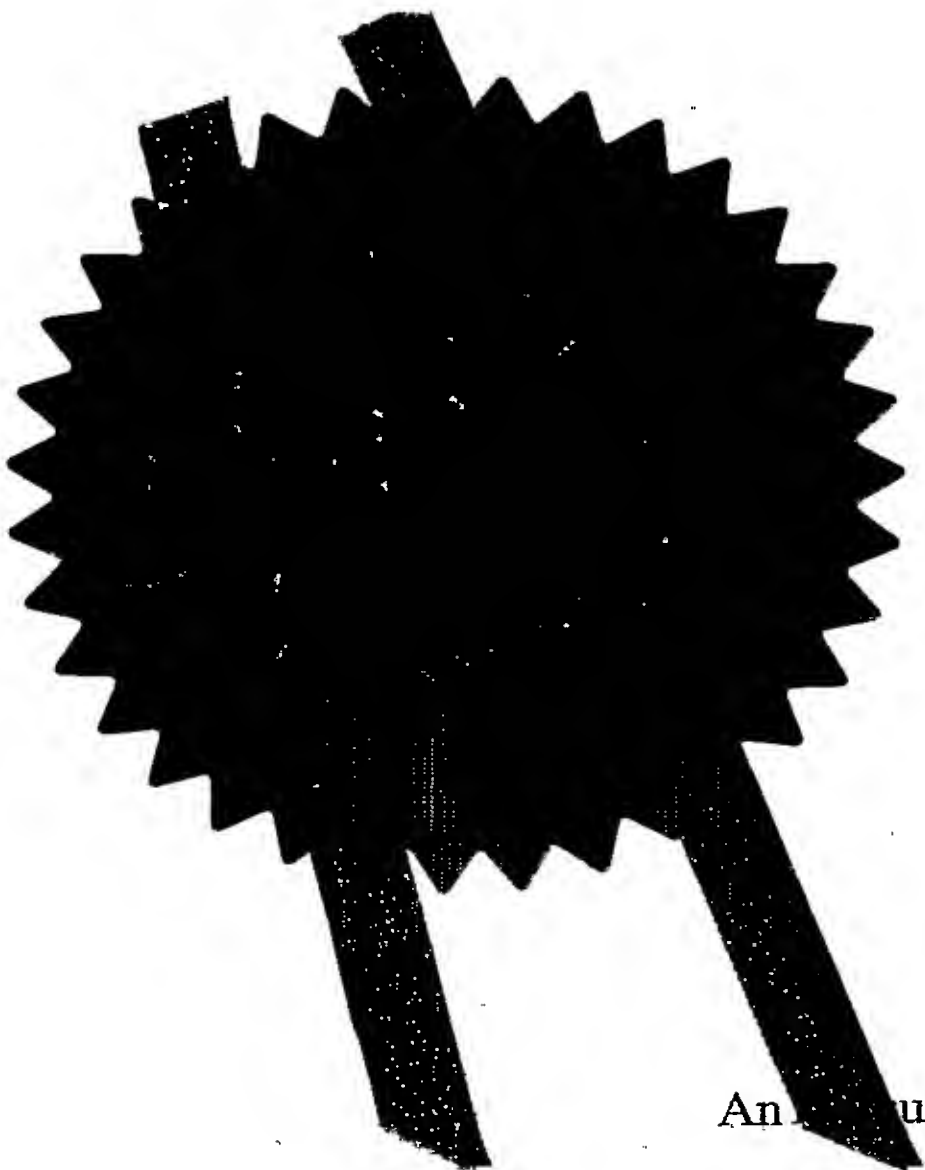
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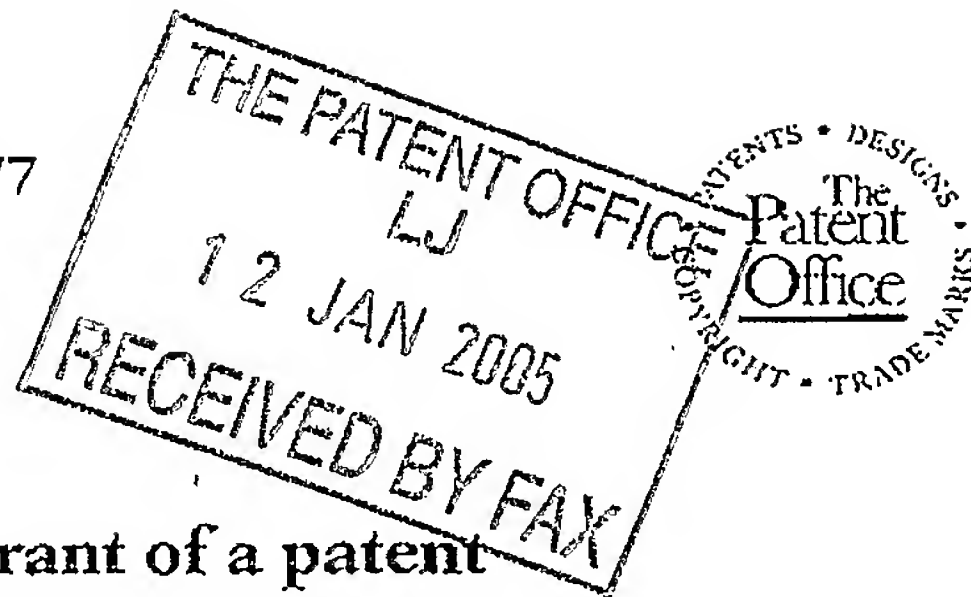
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Patents ADP number (if you know it)			
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4. Title of the invention	"Method and Apparatus for Generating a Mist"		
5. Name of your agent (if you have one)	Murgitroyd & Company		
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Description 69

Claim(s) 9

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1 **Method and Apparatus for Generating a Mist**

2

3 The present invention relates to a method and
4 apparatus for generating a mist and in particular,
5 but not exclusively, to a method and apparatus for
6 the generation of a liquid droplet mist with
7 application to, but not restricted to, water mist
8 generation for fire extinguishing, suppression and
9 control.

10

11 It is well known in the art that there are three
12 major contributing factors required to maintain
13 combustion. These are known as the fire triangle,
14 i.e. fuel, heat and oxygen. Conventional fire
15 extinguishing and suppression systems aim to remove
16 or at least minimise at least one of these major
17 factors. Typically fire suppression systems use
18 inter alia water, CO₂, Halon, dry powder or foam.
19 Water systems act by removing the heat from the
20 fire, whilst CO₂ systems work by displacing oxygen.

21

1 Another aspect of combustion is known as the flame
2 chain reactions. The reaction relies on free
3 radicals that are created in the combustion process
4 and are essential for its continuation. Halon
5 operates by attaching itself to the free radicals
6 and thus preventing further combustion by
7 interrupting the flame chain reaction.

8
9 The major disadvantage of water systems is that a
10 large amount of water is usually required to
11 extinguish the fire. This presents a first problem
12 of being able to store a sufficient volume of water
13 or quickly gain access to an adequate supply. In
14 addition, such systems can also lead to damage by
15 the water itself, either in the immediate region of
16 the fire, or even from water seepage to adjoining
17 rooms. CO2 and Halon systems have the disadvantage
18 that they cannot be used in environments where
19 people are present as it creates an atmosphere that
20 becomes difficult or even impossible for people to
21 breathe in. Halon has the further disadvantage of
22 being toxic and damaging to the environment. For
23 these reasons the manufacture of Halon is being
24 banned in most countries.

25
26 To overcome the above disadvantages a number of
27 alternative systems utilising liquid mist have
28 emerged. The majority of these utilise water as the
29 suppression media, but present it to the fire in the
30 form of a water mist. A water mist system overcomes
31 the above disadvantages of conventional systems by
32 using the water mist to reduce the heat of the

1 vapour around the fire, displace the oxygen and also
2 disrupt the flame chain reaction. Such systems use
3 a relatively small amount of water and are generally
4 intended for class A and B fires, and even
5 electrical fires.

6
7 Current water mist systems utilise a variety of
8 methods for generating the water droplets, using a
9 range of pressures. A major disadvantage of many of
10 these systems is that they require a relatively high
11 pressure to force the water through injection
12 nozzles and/or use relatively small nozzle orifices
13 to form the water mist. Typically these pressures
14 are 20bar or greater. As such, many systems utilise
15 a gas-pressurised tank to provide the pressurised
16 water, thus limiting the run time of the system.
17 Such systems are usually employed in closed areas of
18 known volume such as engine rooms, pump rooms, and
19 computer rooms. However, due to their finite
20 storage capacity, such systems have the limitation
21 of a short run time. Under some circumstances, such
22 as a particularly fierce fire, or if the room is no
23 longer sealed, the system may empty before the fire
24 is extinguished. Another major disadvantage of these
25 systems is that the water mist from these nozzles
26 does not have a particularly long reach, and as such
27 the nozzles are usually fixed in place around the
28 room to ensure adequate coverage.

29
30 Conventional water mist systems use a high pressure
31 nozzle to create the water droplet mist. Due to the
32 droplet formation mechanism of such a system, and

1 the high tendency for droplet coalescence, an
2 additional limitation of this form of mist
3 generation is that it creates a mist with a wide
4 range of water droplet sizes. It is known that
5 water droplets of approximately 40-50µm in size
6 provide the optimum compromise for fire suppression
7 for a number of fire scenarios. For example, a
8 study by the US Naval Research Laboratories found
9 that a water mist with droplets less than 42µm in
10 size was more effective at extinguishing a test fire
11 than Halon 1301. A water mist comprised of droplets
12 in the approximate size range of 40-50µm provides an
13 optimum compromise of having the greatest surface
14 area for a given volume, whilst also providing
15 sufficient mass to project a sufficient distance and
16 also penetrate into the heat of the fire.
17 Conventional water mist systems comprised of
18 droplets with a lower droplet size will have
19 insufficient mass, and hence momentum, to project a
20 sufficient distance and also penetrate into the heat
21 of a fire.

22
23 The majority of conventional water mist systems only
24 manage to achieve a low percentage of the water
25 droplets in this key size range.

26
27 An additional disadvantage of the conventional water
28 mist systems, generating a water mist with such a
29 wide range of droplet sizes, is that the majority of
30 fire suppression requires line-of-sight operation.
31 Although the smaller droplets will tend to behave as
32 a gas the larger droplets in the flow will

1 themselves impact with these smaller droplets so
2 reducing their effectiveness. A mist which behaves
3 more akin to a gas cloud has the advantages of
4 reaching non line-of-sight areas, so eliminating all
5 hot spots and possible re-ignition zones. A further
6 advantage of such a gas cloud behaviour is that the
7 water droplets have more of a tendency to remain
8 airborne, thereby cooling the gases and combustion
9 products of the fire, rather than impacting the
10 surfaces of the room. This improves the rate of
11 cooling of the fire and also reduces damage to items
12 in the vicinity of the fire.

13

14 According to a first aspect of the present invention
15 there is provided an apparatus for generating a mist
16 comprising:

17 a conduit having a mixing chamber and an exit;
18 a transport nozzle in fluid communication with
19 the said conduit, the transport nozzle being adapted
20 to introduce a transport fluid into the mixing
21 chamber;

22 a working nozzle positioned adjacent the
23 transport nozzle intermediate the transport nozzle
24 and the exit, the working nozzle being adapted to
25 introduce a working fluid into the mixing chamber;
26 the transport and working nozzles having an
27 angular orientation and internal geometry such that
28 in use interaction of the transport fluid and
29 working fluid in the mixing chamber causes the
30 working fluid to atomise and form a dispersed
31 vapour/droplet flow regime, which is discharged as a

1 mist from the exit, the mist comprising working
2 fluid droplets having a substantially uniform size.

3
4 Typically at least 60% of the droplets by volume
5 have a size within 30% of the median size, although
6 the invention is not limited to this. In a
7 particularly uniform mist the proportion may be 70%
8 or 80% or more of the droplets by volume having a
9 size within 30%, 25%, 20% or less of the median
10 size.

11
12 Preferably the transport and/or working nozzle
13 substantially circumscribes the conduit.

14
15 Preferably the angular orientation and internal
16 geometry of the transport and working nozzles is
17 such that the size of the working fluid droplets is
18 less than 50 μ m.

19
20 Preferably the mixing chamber includes a converging
21 portion.

22
23 Preferably the mixing chamber includes a diverging
24 portion.

25
26 Preferably the apparatus includes a second transport
27 nozzle being adapted to introduce further transport
28 fluid or a second transport fluid into the mixing
29 chamber.

30
31 Preferably the second transport nozzle is positioned
32 nearer to the exit than the working nozzle, such

1 that the working nozzle is intermediate both
2 transport nozzles.

3

4 Preferably the mixing chamber includes an inlet
5 adapted to introduce an inlet fluid into the mixing
6 chamber, the inlet being distal from the exit, the
7 transport and working nozzles being arranged
8 intermediate the inlet and exit.

9

10 Preferably the apparatus includes a supplementary
11 nozzle arranged inside the transport nozzle and
12 adapted to introduce further transport fluid or a
13 second transport fluid into the mixing chamber.

14

15 Preferably the supplementary nozzle is arranged
16 axially in the mixing chamber.

17

18 Preferably the supplementary nozzle extends forward
19 of the transport nozzle.

20

21 Preferably the supplementary nozzle is shaped with a
22 convergent-divergent profile to provide supersonic
23 flow of the transport fluid which flows
24 therethrough.

25

26 Preferably the transport nozzle is shaped such that
27 the transport fluid introduced into the mixing
28 chamber through the transport nozzle has a divergent
29 or convergent flow pattern.

30

1 Preferably the transport nozzle has inner and outer
2 surfaces each being substantially frustoconical in
3 shape.

4
5 Preferably the working nozzle is shaped such that
6 working fluid introduced into the mixing chamber
7 through the working nozzle has a convergent or
8 divergent flow pattern.

9
10 Preferably the working nozzle has inner and outer
11 surfaces each being substantially frustoconical in
12 shape.

13
14 Preferably the apparatus further includes control
15 means adapted to control one or more of droplet
16 size, droplet distribution, spray cone angle and
17 projection distance.

18
19 Preferably the apparatus further includes control
20 means to control one or more of the flow rate,
21 pressure, velocity, quality, and temperature of the
22 working or transport fluids.

23
24 Preferably the control means includes means to
25 control the angular orientation and internal
26 geometry of the transport and working nozzles.

27
28 Preferably the control means includes means to
29 control the internal geometry of at least part of
30 the mixing chamber or exit to vary it between
31 convergent and divergent.

32

- 1 Preferably the internal geometry of the transport
2 nozzles has an area ratio, namely exit area to
3 throat area, in the range 1.75 to 15, having an
4 included angle α substantially equal to or less than
5 6 degrees for supersonic flow and substantially
6 equal to or less than 12 degrees for sub-sonic flow.
7
- 8 Preferably the transport nozzle is oriented at an
9 angle β of between 0 to 30 degrees.
10
- 11 Preferably the mixing chamber is closed upstream of
12 the transport nozzle.
13
- 14 Preferably the exit of the apparatus is provided
15 with a cowl to control the mist.
16
- 17 Preferably the cowl comprises a plurality of
18 separate sections arranged radially, each section
19 adapted to control and re-direct a portion of the
20 discharge of mist emerging from the exit.
21
- 22 Preferably the apparatus is located within a further
23 cowl.
24
- 25 Preferably the conduit includes a passage.
26
- 27 Preferably at least one of the passage, the
28 transport nozzle(s), working nozzle(s) and
29 supplementary nozzle(s) has a turbulator to induce
30 turbulence of the fluid therethrough prior to the
31 fluid being introduced into the mixing chamber.
32

1 According to a second aspect of the present
2 invention there is provided a method of generating a
3 mist comprising the steps of:

4 providing apparatus for generating a mist
5 comprising a transport and working nozzle and a
6 conduit, the conduit having a mixing chamber and an
7 exit;

8 introducing a stream of transport fluid into
9 the mixing chamber through the transport nozzle;

10 introducing a working fluid into the mixing
11 chamber through the working nozzle downstream of the
12 transport nozzle nearer to the exit;

13 atomising the working fluid by interaction of
14 the transport fluid with the working fluid to form a
15 dispersed vapour/droplet flow regime; and

16 discharging the dispersed vapour/droplet flow
17 regime through the exit as a mist comprising working
18 fluid droplets of substantially uniform size.

19
20 Preferably the apparatus is any apparatus according
21 to the first aspect of the present invention.

22
23 Preferably the stream of transport fluid introduced
24 into the mixing chamber is annular.

25
26 Preferably the working fluid droplets have a size
27 less than 50 μ m.

28
29 Preferably the method includes the step of
30 introducing the transport fluid into the mixing
31 chamber in a continuous or discontinuous or
32 intermittent or pulsed manner.

1
2 Preferably the method includes the step of
3 introducing the transport fluid into the mixing
4 chamber as a supersonic flow.

5
6 Preferably the method includes the step of
7 introducing the working fluid into the mixing
8 chamber in a continuous or discontinuous or
9 intermittent or pulsed manner.

10
11 Preferably the method includes the step of
12 introducing the transport fluid into the mixing
13 chamber as a sub-sonic flow.

14
15 Preferably the mist is controlled by modulating at
16 least one of the following parameters:
17 the flow rate, pressure, velocity, quality
18 and/or temperature of the transport fluid;
19 the flow rate, pressure, velocity, quality
20 and/or temperature of the working fluid;
21 the flow rate, pressure, velocity, quality
22 and/or temperature of the inlet fluid;
23 the angular orientation of the transport and/or
24 working and/or supplementary nozzle(s) of the
25 apparatus;
26 the internal geometry of the transport and/or
27 working and/or supplementary nozzle(s) of the
28 apparatus; and
29 the internal geometry, length and/or cross
30 section of the mixing chamber.

31

- 1 Preferably the method includes mixing the transport
- 2 and working fluid together by means of a high
- 3 velocity transport fluid jet issuing from the
- 4 transport nozzle.
- 5
- 6 Preferably the method includes the generation of
- 7 condensation shocks and/or momentum transfer to
- 8 provide suction within the apparatus.
- 9
- 10 Preferably the method includes inducing turbulence
- 11 of the inlet fluid prior to it being introduced into
- 12 the mixing chamber.
- 13
- 14 Preferably the method includes inducing turbulence
- 15 of the working fluid prior to it being introduced
- 16 into the mixing chamber.
- 17
- 18 Preferably the method includes inducing turbulence
- 19 of the transport fluid prior to it being introduced
- 20 into the mixing chamber.
- 21
- 22 Preferably the transport fluid is steam or an
- 23 air/steam mixture.
- 24
- 25 Preferably the working fluid is water or a water-
- 26 based liquid.
- 27
- 28 Preferably the mist is used for fire suppression.
- 29
- 30 Preferably the mist is used for decontamination.
- 31
- 32 Preferably the mist is used for gas scrubbing.

1
2 Embodiments of the present invention will now be
3 described, by way of example only, with reference to
4 the accompanying drawings in which:

5
6 Fig. 1 is a cross-sectional elevation view of an
7 apparatus for generating a mist in accordance with a
8 first embodiment of the present invention;

9
10 Figs. 2 to 4 are schematics showing an over expanded
11 transport nozzle, an under expanded transport
12 nozzle, and a largely over expanded transport
13 nozzle, respectively;

14
15 Figs. 5 to 10 show alternative arrangements of a
16 contoured passage to initiate turbulence;

17
18 Fig. 11 is a schematic showing the interaction of a
19 transport and working fluid as they issue from a
20 transport and working nozzle;

21
22 Fig. 12 is a cross-sectional elevation view of an
23 alternative embodiment of the apparatus of Fig. 1
24 having a diverging mixing chamber;

25
26 Fig. 13 is a cross-sectional elevation view of an
27 alternative embodiment of the apparatus of Fig. 12
28 having an additional transport nozzle;

29
30 Fig. 14 is a cross-sectional elevation view of the
31 apparatus of Fig. 1 enclosed in a casing;

32

1 Fig. 15 is a cross-sectional elevation view of an
2 apparatus for generating a mist substantially
3 similar to Fig. 1 save that a mixing chamber has
4 been closed upstream;
5
6 Fig. 16 is a cross-sectional elevation view of an
7 apparatus for generating a mist in accordance with
8 an alternative embodiment of the present invention;
9
10 Fig. 17 is a cross-sectional elevation view of an
11 alternative embodiment of the apparatus of Fig. 16
12 having an additional transport nozzle;
13
14 Fig. 18 is a cross-sectional elevation view of an
15 apparatus for generating a mist in accordance with a
16 further alternative embodiment of the present
17 invention;
18
19 Fig. 19 is a cross-sectional elevation view of an
20 additional embodiment of the apparatus of Fig. 18
21 having an additional transport nozzle;
22
23 Fig. 20 is a cross-sectional elevation view of an
24 apparatus for generating a mist in accordance with
25 yet a further embodiment of the present invention;
26 and
27
28 Fig. 21 is a cross-sectional elevation view of the
29 apparatus of Fig. 20 having a modification.
30

1 Where appropriate, like reference numerals have been
2 substantially used for like parts throughout the
3 specification.

4
5 Referring to Fig. 1 there is shown an apparatus for
6 generating a mist, a mist generator 1, comprising a
7 conduit or housing 2 defining a passage 3 providing
8 an inlet 4 for the introduction of an inlet fluid,
9 an outlet or exit 5, and a mixing chamber 3A, the
10 passage 3 being of substantially constant circular
11 cross section.

12
13 The passage 3 may be of any convenient cross-
14 sectional shape suitable for the particular
15 application of the mist generator 1. The passage 3
16 shape may be circular, rectilinear or elliptical, or
17 any intermediate shape, for example curvilinear.

18
19 The mixing chamber 3A is of constant cross-sectional
20 area but the cross-sectional area may vary along the
21 mixing chamber's length with differing degrees of
22 reduction or expansion, i.e. the cross-sectional
23 area of the mixing chamber may taper at different
24 angles at different points along its length. The
25 mixing chamber may taper from the location of the
26 transport nozzle 16 and the taper ratio may be
27 selected such that the multi-phase flow velocity and
28 trajectory is maintained at its optimum or desired
29 position.

30
31 The mixing chamber 3A is of variable length in order
32 to provide a control on the mist's droplet formation

1 parameters, i.e. droplet size, droplet
2 density/distribution, velocity (projected distance)
3 and spray cone angle. The length of the mixing
4 chamber is thus chosen to provide the optimum
5 performance regarding momentum transfer and to
6 enhance turbulence. In some embodiments the length
7 may be adjustable in situ rather than pre-designed
8 in order to provide a measure of versatility.

9
10 The mixing chamber geometry is determined by the
11 desired and projected output performance of the
12 discharge of mist and to match the designed steam
13 conditions and nozzle geometry. In this respect it
14 will be appreciated that there is a combinatory
15 effect as between the various geometric features and
16 their effect on performance, namely droplet size,
17 droplet density, mist spray cone angle and projected
18 distance.

19
20 The inlet 4 is formed at a front end of a protrusion
21 6 extending into the housing 2 and defining
22 exteriorly thereof a chamber or plenum 8 for the
23 introduction of a transport fluid into the mixing
24 chamber 3A, the plenum 8 being provided with a
25 transport fluid feed port 10. The protrusion 6
26 defines internally thereof part of the passage 3.

27
28 The transport fluid is steam, but may be any
29 compressible fluid, such as a gas or vapour, or may
30 be a mixture of compressible and flowable fluids.
31 It is envisaged that to allow a quick start to the
32 mist generator 1, the transport fluid can initially

1 be air. Meanwhile, a rapid steam generator or other
2 means can be used to generate steam. Once the steam
3 is formed, the air supply can be switched to the
4 steam supply. It is also envisaged that air or
5 other compressible fluids and/or flowable fluids can
6 be used to regulate the temperature of the transport
7 fluid, which in turn can be used to control the mist
8 droplet formation.

9
10 A distal end 12 of the protrusion 6 remote from the
11 inlet 4 is tapered on its relatively outer surface
12 14 and defines a transport nozzle 16 between it and
13 a correspondingly tapered part 18 of the inner wall
14 of the housing 2, the transport nozzle 16 being in
15 fluid communication with the plenum 8.

16
17 The transport nozzle 16 is so shaped (with a
18 convergent-divergent portion) as in use to give
19 supersonic flow of the transport fluid into the
20 mixing chamber 3A. For a given steam condition,
21 i.e. dryness (quality), pressure, velocity and
22 temperature, the transport nozzle 16 is preferably
23 configured to provide the highest velocity steam
24 jet, the lowest pressure drop and the highest
25 enthalpy between the plenum and nozzle exit.
26 However, it is envisaged that the flow of transport
27 fluid into the mixing chamber may alternatively be
28 sub-sonic in some applications for application or
29 process requirements, or transport fluid and/or
30 working fluid property requirements. For instance,
31 the jet issuing from a sub-sonic flow will be easier
32 to divert compared with a supersonic jet.

1 Accordingly, a transport nozzle could be adapted
2 with deflectors to give a wider cone angle than
3 supersonic flow conditions. However, whilst sub-
4 sonic flow may provide a wider spray cone angle,
5 there is a trade-off with an increase in the mist's
6 droplet size; but in some applications this may be
7 acceptable.

8

9 Thus, the transport nozzle 16 corresponds with the
10 shape of the passage 3, for example, a circular
11 passage would advantageously be provided with an
12 annular nozzle circumscribing the said passage.

13

14 It is anticipated that the transport nozzle 16 may
15 be a single point nozzle which is located at some
16 point around the circumference of the passage to
17 introduce transport fluid into the mixing chamber.
18 However, an annular configuration will be more
19 effective compared with a single point nozzle.

20

21 The term "annular" as used herein is deemed to
22 embrace any configuration of nozzle or nozzles that
23 circumscribes the passage 3 of the mist generator 1,
24 and encompasses circular, irregular, polygonal,
25 elliptical and rectilinear shapes of nozzle.

26

27 In the case of a rectilinear passage, which may have
28 a large width to height ratio, transport nozzles
29 would be provided at least on each transverse wall,
30 but not necessarily on the sidewalls, although the
31 invention optionally contemplates a full
32 circumscription of the passage by the nozzles

1 irrespective of shape. For example the mist
2 generator could be made to fit a standard door
3 letterbox to allow fire fighters to easily treat a
4 house fire without the need to enter the building.
5 Size scaling is important in terms of being able to
6 readily accommodate differing designed capacities in
7 contrast to conventional equipment.

8
9 The transport nozzle 16 has an area ratio, defined
10 as exit area to throat area, in the range 1.75 to 15
11 with an included angle (α) substantially equal to or
12 less than 6 degrees for supersonic flow, and
13 substantially equal to or less than 12 degrees for
14 sub-sonic flow; although the included angle (α) may
15 be greater. The angular orientation of the
16 transport nozzle 16 is $\beta = 0$ to 30 degrees relative
17 to the boundary flow of fluid within the conduit at
18 the nozzle's exit. However, the angle β may be
19 greater.

20
21 The transport nozzle 16 may, depending on the
22 application of the mist generator 1, have an
23 irregular cross section. For example, there may be
24 an outer circular nozzle having an inner ellipsoid
25 or elliptical nozzle which both can be configured to
26 provide particular flow patterns, such as swirl, in
27 the mixing chamber to increase the intensity of the
28 shearing effect and turbulence.

29
30 A working nozzle 34, located downstream of the
31 transport nozzle 16 nearer to the exit 5, is formed
32 in a second plenum 32 provided in the housing 2.

1 The working nozzle 34 is annular and circumscribes
2 the passage 3.

3
4 The working nozzle 34 corresponds with the shape of
5 the passage 3 and/or the transport nozzle 16 and
6 thus, for example, a circular passage would
7 advantageously be provided with an annular working
8 nozzle circumscribing said passage. However, it is
9 to be appreciated that the working nozzle 34 need
10 not be annular, or indeed, need not be a nozzle.
11 The working nozzle 34 need only be an inlet to allow
12 a working fluid to be introduced into the mixing
13 chamber 3A.

14
15 In the case of a rectilinear passage, which may have
16 a large width to height ratio, working nozzles would
17 be provided at least on each transverse wall, but
18 not necessarily on the sidewalls, although the
19 invention optionally contemplates a full
20 circumscription of the passage by the working nozzle
21 irrespective of shape.

22
23 The working nozzle 34 may be used for the
24 introduction of gases or liquids or of other
25 additives that may, for example, be treatment
26 substances for the working fluid or may be
27 particulates in powder or pulverant form to be mixed
28 with the working fluid. For example, water and an
29 additive may be introduced together via a working
30 nozzle (or separately via two working nozzles) for
31 water mist applications. The working fluid and
32 additive are entrained into the mist generator 1 by

1 the low pressure created within the mist generator
2 (mixing chamber). The fluids or additives may also
3 be pressurised by an external means and pumped into
4 the mist generator, if required.

5
6 For fire fighting applications, typically the
7 working fluid is water, but may be any flowable
8 fluid or mixture of flowable fluids requiring to be
9 dispersed into a mist, e.g. any non-flammable liquid
10 or flowable fluid (inert gas) which absorbs heat
11 when it vaporises may be used instead of, or in
12 addition to via a second working nozzle, the water.

13
14 The working nozzle 34 may be located as close as
15 possible to the projected surface of the transport
16 fluid issuing from the transport nozzle 16. In
17 practice and in this respect a knife edge separation
18 between the transport fluid stream and the working
19 fluid stream issuing from their respective nozzles
20 may be of advantage in order to achieve the
21 requisite degree of interaction of said fluids. The
22 angular orientation of the transport nozzle 16 with
23 respect to the stream of the working fluid is of
24 importance.

25
26 The transport nozzle 16 is conveniently angled
27 towards the stream of working fluid issuing from the
28 working nozzle 34 since this occasions penetration
29 of the working fluid. The angular orientation of
30 both nozzles is selected for optimum performance to
31 enhance turbulence, which is dependent inter alia on
32 the nozzle orientation and the internal geometry of

1 the mixing chamber, to achieve a desired droplet
2 formation (i.e. size, distribution, spray cone angle
3 and projection). Moreover, the creation of
4 turbulence, governed inter alia by the angular
5 orientation of the nozzles, is important to achieve
6 optimum performance by dispersal of the working
7 fluid in order to increase acceleration by momentum
8 transfer and mass transfer.

9
10 Simply put, the more turbulence there is generated,
11 the smaller the droplet size achievable.

12
13 Figs. 2 to 4 show schematics of different
14 configurations of the transport and working nozzles,
15 which provide different degrees of turbulence.

16
17 Fig. 2 shows an over expanded transport nozzle. The
18 transport nozzle can be configured to provide a
19 particular steam pressure gradient across it. One
20 parameter that can be changed/controlled is the
21 degree of expansion of the steam through the nozzle.
22 Different steam exit pressures provide different
23 steam exit velocities and temperatures with a
24 subsequent effect on the droplet formation of the
25 mist.

26
27 With an over expanded nozzle the steam exiting the
28 transport nozzle is over expanded such that its
29 local pressure is less than local atmospheric
30 pressure. For example, typical pressures are 0.7 to
31 0.8 bar absolute, with a subsequent steam
32 temperature of approximately 85°C.

1
2 This results in the formation of very weak shocks in
3 the flow. The advantages of this arrangement is
4 that the steam velocity is high, therefore there is
5 a very high primary and secondary break up, which
6 results in relatively smaller droplets. It can also
7 be quieter in operation than other nozzle
8 arrangements (as will be discussed), due to the lack
9 of strong shocks.

10
11 There is a trade-off though in that there is reduced
12 suction pressure created within the mist generator
13 due to the lack of condensation shocks. However,
14 this feature is only desired to entrain the inlet or
15 working fluid through the mist generator rather than
16 pumping it in.

17
18 Fig. 3 shows an under expanded transport nozzle.
19 With under expanded nozzles the exit steam pressure
20 is higher than local atmospheric pressure, for
21 example it can be approximately 1.2 bar absolute, at
22 a temperature of approximately 115°C. This results
23 in local expansion and condensation shocks. A
24 higher temperature differential between the steam
25 and water can exist, therefore local condensation
26 shocks are generated. This results in a higher
27 suction pressure being generated through the mist
28 generator for the entrainment of the working fluid
29 and inlet fluid.

30
31 However, there is a trade-off in that an under
32 expanded nozzle has a lower steam velocity,

1 resulting in a less efficient primary and secondary
2 break up, leading to slightly larger droplet sizes.

3

4 Fig. 4 shows a largely over expanded transport
5 nozzle. This alternative arrangement has a typical
6 exit pressure of approximately 0.2 bar absolute.
7 However, the exit velocity can be very high,
8 typically approximately 1500m/s (approximately Mach
9 3). This high velocity results in the generation of
10 a very strong localised aerodynamic shock (normal
11 shock) at the steam exit. This shock is so strong
12 that theoretically downstream of the shock the
13 pressure increases to approximately 1.2bar absolute
14 and rises to a temperature of approximately 120°C.
15 This higher temperature may help to reduce the
16 surface tension of the water, so helping to reduce
17 the droplet size. This resultant higher temperature
18 can be used in applications where heat treatment of
19 the working and/or inlet fluid is required, such as
20 the treatment of bacteria.

21

22 However, the trade-off with this arrangement is that
23 the strong shocks reduce the velocity of the steam,
24 therefore there is a reduced effect on the high
25 shear droplet break up mechanism. In addition, it
26 may be noisy.

27

28 In operation the inlet 4 is connected to a source of
29 inlet fluid which is introduced into the inlet 4 and
30 passage 3. In this specific example relating to
31 fire suppression, the inlet fluid is air, but may be
32 any flowable fluid or mixture of flowable fluids.

1

2 The working fluid, water, is introduced into a feed
3 port 30, where the water flows into the plenum 32,
4 and out through the working nozzle 34.

5

6 However, it is anticipated that working fluid may be
7 introduced into the mixing chamber via the inlet 4,
8 where a second working fluid may be introduced into
9 the mixing chamber via a working nozzle.

10

11 The transport fluid, steam, is introduced into the
12 feed port 10, where the steam flows into the plenum
13 8, and out through the transport nozzle 16 as a high
14 velocity steam jet.

15

16 The high velocity steam jet issuing from the
17 transport nozzle 16 impacts with the water stream
18 issuing from the nozzle 34 with high shear forces,
19 thus atomising the water breaking it into fine
20 droplets and producing a well mixed three-phase
21 condition constituted by the liquid phase of the
22 water, the steam and the air. In this instance, the
23 energy transfer mechanism of momentum and mass
24 transfer occasion's induction of the water through
25 the mixing chamber 3A and out of the exit 5. Mass
26 transfer will generally only occur for hot transport
27 fluids, such as steam.

28

29 In simple terms, the present invention uses the
30 transport fluid to slice up the working fluid. As
31 already touched on, the more turbulence you have,
32 the smaller the droplets formed.

1
2 The present invention has a primary break up
3 mechanism and a secondary break up mechanism to
4 atomise the working fluid. The primary mechanism is
5 the high shear between the steam and the water,
6 which is a function of the high relative velocities
7 between the two fluids, resulting in the formation
8 of small waves on the boundary surface of the water
9 surface, ultimately forming ligaments which are
10 stripped off.

11
12 The secondary break up mechanism involves two
13 aspects. The first is further shear break up, which
14 is a function of any remaining slip velocities
15 between the water and the steam. However, this
16 reduces as the water ligaments/droplets are
17 accelerated up to the velocity of the steam. The
18 second aspect is turbulent eddie break up of the
19 water droplets caused by the turbulence of the
20 steam. The turbulent eddie break up is a function
21 of transport nozzle exit velocities, local
22 turbulence, nozzle orientation (this effects the way
23 the mist interacts with itself), and the surface
24 tension of the water (which is effected by the
25 temperature).

26
27 The primary break up mechanism of the working fluid
28 may be enhanced by creating initial instabilities in
29 the working fluid flow. Deliberately created
30 instabilities in the transport fluid/working fluid
31 interaction layer encourages fluid surface turbulent
32 dissipation resulting in the working fluid

1 dispersing into a liquid-ligament region, followed
2 by a ligament-droplet region where the ligaments and
3 droplets are still subject to disintegration due to
4 aerodynamic characteristics.

5
6 The interaction between the transport fluid and the
7 working fluid, leading to the atomisation of the
8 working fluid, is enhanced by flow instability.
9 Instability enhances the droplet stripping from the
10 contact surface of the flow of the working fluid. A
11 turbulent dissipation layer between the transport
12 and working fluids is both fluidically and
13 mechanically (geometry) encouraged ensuring rapid
14 fluid dissipation.

15
16 The internal walls of the flow passage immediately
17 upstream of the transport nozzle 16 exit may be
18 contoured to provide different degrees of turbulence
19 to the working fluid prior to its interaction with
20 the transport fluid issuing from the or each nozzle.

21
22 Fig. 5 shows the internal walls of the passage 3
23 provided with a contoured internal wall in the
24 region 19 immediately upstream of the exit of the
25 transport nozzle 16 is provided with a tapering wall
26 130 to provide a diverging profile leading up to the
27 exit of the transport nozzle 16. The diverging wall
28 geometry provides a deceleration of the localised
29 flow, providing disruption to the boundary layer
30 flow, in addition to an adverse pressure gradient,
31 which in turn leads to the generation and

1 propagation of turbulence in this part of the
2 working fluid flow.

3
4 An alternative embodiment is shown in Fig. 6, which
5 shows the internal wall 19 of the flow passage 3
6 immediately upstream of the transport nozzle 16
7 being provided with a diverging wall 130 on the bore
8 surface leading up to the exit of the transport
9 nozzle 16, but the taper is preceded with a step
10 132. In use, the step results in a sudden increase
11 in the bore diameter prior to the tapered section.
12 The step 'trips' the flow, leading to eddies and
13 turbulent flow in the working fluid within the
14 diverging section, immediately prior to its
15 interaction with the steam issuing from the
16 transport nozzle 16. These eddies enhance the
17 initial wave instabilities which lead to ligament
18 formation and rapid working fluid dispersion.

19
20 The tapered diverging section 130 could be tapered
21 over a range of angles and may be parallel with the
22 walls of the bore. It is even envisaged that the
23 tapered section 130 may be tapered to provide a
24 converging geometry, with the taper reducing to a
25 diameter at its intersection with the transport
26 nozzle 16 which is preferably not less than the bore
27 diameter.

28
29 The embodiment shown in Fig. 6 is illustrated with
30 the initial step 132 angled at 90° to the axis of
31 the bore 3. As an alternative to this
32 configuration, the angle of the step 132 may display

1 a shallower or greater angle suitable to provide a
2 'trip' to the flow. Again, the diverging section
3 130 could be tapered at different angles and may
4 even be parallel to the walls of the bore 3.
5 Alternatively, the tapered section 130 may be
6 tapered to provide a converging geometry, with the
7 taper reducing to a diameter at its intersection
8 with the transport nozzle 16 which is preferably not
9 less than the bore diameter.

10
11 Figs. 7 to 10 illustrate examples of alternative
12 contoured profiles 134, 136, 138, 140. All of these
13 are intended to create turbulence in the working
14 fluid flow immediately prior to the interaction with
15 the transport fluid issuing from the transport
16 nozzle 16.

17
18 Although Figs. 5 to 10 illustrate several
19 combinations of grooves and tapering sections, it is
20 envisaged that any combination of these features, or
21 any other groove cross-sectional shape may be
22 employed.

23
24 Similarly, the transport, working and supplementary
25 nozzles, and the mixing chamber, may be adapted with
26 such contours to enhance turbulence.

27
28 The length of the mixing chamber 3A can be used as a
29 parameter to increase turbulence, and hence,
30 decrease the droplet size, leading to an increased
31 cooling rate.

32

1 Fig. 11 shows a schematic of the interaction of the
2 working and transport flows as they issue from their
3 respective nozzles. Current thinking suggests that
4 optimum performance is achieved when the length of
5 the mixing chamber is limited to the point where the
6 increasing thickness boundary layer between the
7 steam and the water touches the inner surface of the
8 housing 2. Keeping the mixing chamber short like
9 this also allows air to be entrained at the exit 5
10 from the outside surface of the mist generator,
11 where the entrained air increases the mixing and
12 turbulence intensity, and therefore, the mist's
13 droplet formation. In other words, increased
14 intensity of the turbulence allows for the
15 generation of smaller working fluid droplets within
16 the mist. The advantage of having smaller water
17 droplets is that they have a relatively increased
18 cooling rate compared with larger droplet sizes.

19
20 The properties or parameters of the inlet fluid,
21 working fluid and transport fluid, for example,
22 quality, flow rate, velocity, pressure and
23 temperature, can be regulated or controlled or
24 manipulated to give the required intensity of
25 shearing and hence, the required droplet size,
26 droplet distribution, spray cone angle and
27 projection distance. The properties of the inlet,
28 working and transport fluids being controllable by
29 either external means, such as a pressure regulation
30 means, and/or by the angular orientation and
31 internal geometry of the nozzles 16, 34.

32

1 The quality of the inlet and working fluids refer to
2 its purity, viscosity, density, and the
3 presence/absence of contaminants.

4
5 The mechanism of the present invention primarily
6 relies on the momentum transfer between the
7 transport fluid and the working fluid, which
8 provides for shearing of the working fluid on a
9 continuous basis by shear dispersion and/or
10 dissociation, plus provides the driving force to
11 propel the generated mist out of the exit. However,
12 when the transport fluid is a hot compressible gas,
13 for example steam, i.e. the transport fluid is of a
14 higher temperature than the working fluid, it is
15 thought that this mechanism is further enhanced with
16 a degree of mass transfer between the transport
17 fluid and the working fluid as well. Again, when
18 the transport fluid is hotter than the working fluid
19 the heat transfer between the fluids and the
20 resulting increase in temperature of the working
21 fluid further aids the dissociation of the liquid
22 into smaller droplets by reducing the viscosity and
23 surface tension of the liquid.

24
25 The intensity of the shearing mechanism, and
26 therefore the size of the droplets created, and the
27 propelling force of the mist, is controllable by
28 manipulating the various parameters prevailing
29 within the mist generator 1 when operational.
30 Accordingly the flow rate, pressure, velocity,
31 temperature and quality, e.g. in the case of steam
32 the dryness, of the transport fluid, may be

1 regulated to give a required intensity of shearing,
2 which in turn leads to the mist emerging from the
3 exit having a homogeneous working fluid droplet
4 distribution having droplets which are of
5 substantially uniform size, a substantial portion of
6 which have a size less than 50 μ m.

7
8 Similarly, the flow rate, pressure, velocity,
9 quality and temperature of the fluids which make up
10 the inlet and working fluids, which are either
11 entrained into the mist generator by the mist
12 generator itself (due to shocks and the momentum
13 transfer between the transport and working fluids)
14 or by external means, may be regulated to give the
15 required intensity of shearing and desired droplet
16 size.

17
18 In carrying out the method of the present invention
19 the creation and intensity of the dispersed droplet
20 flow is occasioned by the design of the transport
21 nozzle 16 interacting with the setting of the
22 desired parametric conditions, for example, in the
23 case of steam as the transport fluid, the pressure,
24 the dryness or steam quality, the velocity, the
25 temperature and the flow rate, to achieve the
26 required performance of the transport nozzle, i.e.
27 generation of a water mist with a substantially
28 uniform droplet distribution, a substantial portion
29 of which have a size less than 50 μ m.

30
31 The performance of the present invention can be
32 complimented with the choice of materials from which

1 it is constructed. Although the chosen materials
2 have to be suitable for the temperature, steam
3 pressure and working fluid, there are no other
4 restrictions on choice. For example, high
5 temperature composites, stainless steel, or
6 aluminium could be used.

7
8 The nozzles may advantageously have a surface
9 coating. This will help reduce wear of the nozzles,
10 and avoid any build up of agglomerates/deposits
11 therein, amongst other advantages.

12
13 The nozzles 16, 34 may be continuous (annular) or
14 may be discontinuous in the form of a plurality of
15 apertures, e.g. segmental, arranged in a
16 circumscribing pattern that may be circular. In
17 either case each aperture may be provided with
18 substantially helical or spiral vanes formed in
19 order to give in practice a swirl to the flow of the
20 transport fluid and working fluid respectively.
21 Alternatively swirl may be induced by introducing the
22 transport/working fluid into the mist generator in
23 such a manner that the transport/working fluid flow
24 induces a swirling motion in to and out of each
25 nozzle 16, 34. For example, in the case of an
26 annular transport nozzle, and with steam as the
27 transport fluid, the steam may be introduced via a
28 tangential inlet off-centre of the axial plane,
29 thereby inducing swirl in the plenum before passing
30 through the transport nozzle. The same would apply
31 to an annular working nozzle where the working fluid
32 would induce a swirl before passing through the

1 working nozzle. As a further alternative the
2 transport and working nozzles may circumscribe the
3 passage in the form of a continuous substantially
4 helical or spiral scroll over a length of the
5 passage, the nozzle apertures being formed in the
6 wall of the passage.

7
8 Whilst the nozzles 16, 34 are shown in Fig. 1 as
9 being directed towards the exit 5, it is also
10 envisaged that the working nozzle 34 may be
11 directed/angled towards the inlet 4, which may
12 result in greater turbulence. Also, the working
13 nozzle 34 may be provided at any angle up to 180
14 degrees relative to the transport nozzle in order to
15 produce greater turbulence by virtue of the higher
16 shear associated with the increasing slip velocities
17 between the transport and working fluids. For
18 example, the working nozzle may be provided
19 perpendicular to the transport nozzle.

20
21 In some embodiments of the present invention a
22 series of transport nozzles is provided lengthwise
23 of the passage 3 and the geometry of the nozzles may
24 vary from one to the other dependent upon the effect
25 desired. For example, the angular orientation may
26 vary one to the other. The nozzles may have
27 differing geometries to afford different effects,
28 i.e. different performance characteristics, with
29 possibly differing parametric transport conditions.
30 For example some nozzles may be operated for the
31 purpose of initial mixing of different liquids and
32 gasses whereas other nozzles are used simultaneously

1 for additional droplet break up or flow
2 directionalisation. Each nozzle may have a mixing
3 chamber section downstream thereof. In the case
4 where a series of nozzles is provided, the number of
5 transport nozzles and working nozzles is optional.

6
7 A cowl (not shown) may be provided downstream of the
8 exit 5 from the passage 3 in order to further
9 control the mist. The cowl may comprise a number of
10 separate sections arranged in the radial direction,
11 each section controlling and re-directing a portion
12 of the mist spray emerging from the exit 5 of the
13 mist generator 1.

14
15 Fig. 12 shows an embodiment of the present invention
16 substantially similar to that shown in Fig. 1 save
17 that the mist generator 1 is provided with a
18 diverging mixing chamber section 3A, and the angular
19 orientation (β) of the nozzles 16, 34 have been
20 adjusted and angled to provide the desired
21 interaction between the steam (transport fluid) and
22 the water (working fluid) occasioning the optimum
23 energy transfer by momentum and mass transfer to
24 enhance turbulence.

25
26 This embodiment operates in substantially the same
27 way as previous embodiments save that this
28 embodiment provides a more diffuse or wider spray
29 cone angle and therefore a wider discharge of mist
30 coverage. Angled walls 36 of the mixing chamber 3A
31 may be angled at different divergent and convergent

1 angles to provide different spray cone angles and a
2 wider discharge of mist coverage.

3
4 Referring now to Fig. 13, which shows an embodiment
5 of the present invention substantially similar to
6 that illustrated in Fig. 12 save that an additional
7 transport fluid feed port 40 and plenum 42 are
8 provided in housing 2, together with a second
9 transport nozzle 44 formed at a location downstream
10 of the working nozzle 34 nearer to the exit 5.

11
12 The second transport nozzle 44 is used to introduce
13 the transport fluid (steam) into the mixing chamber
14 3A downstream of the working fluid (water). The
15 second transport nozzle may be used to introduce a
16 second transport fluid.

17
18 In this embodiment the three nozzles 16, 34, 44 are
19 located coincident with one another thus providing a
20 co-annular nozzle arrangement.

21
22 This embodiment is provided with a diverging mixing
23 chamber section 3A and the angles of the nozzles 16,
24 34, 44 are angled to provide the desired angles of
25 interaction between the two streams of steam and the
26 water, thus occasioning the optimum energy transfer
27 by momentum and mass transfer to enhance turbulence.
28 The diverging walls 36 of the mixing chamber provide
29 a more diffuse or wider spray cone angle and
30 therefore a wider discharge of mist coverage. The
31 angle of the walls 36 of the mixing chamber 3A may

1 be varied convergent-divergent to provide different
2 spray cone angles.

3
4 In operation two high velocity streams of steam exit
5 their respective transport nozzles 16, 44, and
6 sandwich the water stream issuing from the working
7 nozzle 34. This embodiment both enhances the
8 droplet formation by providing a double shearing
9 action, and also provides a fluid separation or
10 cushion between the water and the walls 36 of the
11 mixing chamber 3A, thus preventing small water
12 droplets being lost through coalescence on the
13 angled walls 36 of the mixing chamber 3A before
14 exiting the mist generator 1 via the exit 5. In
15 alternative embodiments, not shown, the mixing
16 chamber section 3A may be converging. This will
17 provide a greater exit velocity for the discharge of
18 mist and therefore a greater projection range.

19
20 With reference to Fig. 14, the mist generator 1 of
21 Fig. 1 is disposed centrally within a cowl or casing
22 50. The casing 50 comprises a diverging inlet
23 portion 52 having an inlet opening 54, a central
24 portion 56 of constant cross-section, leading to a
25 converging outlet portion 58, the outlet portion 58
26 having an outlet opening 60.

27
28 In use the inlet opening 54 and the outlet opening
29 60 are in fluid communication with a body of the
30 inlet fluid (air) either therewithin or connected to
31 a conduit. Although Fig. 14 illustrates use of the
32 mist generator 1 of Fig. 1 disposed centrally within

1 the casing 50, it is envisaged that any of the
2 embodiments of the present invention may also be
3 used instead.

4
5 In operation the inlet fluid (air) is drawn through
6 the casing 50 (by shocks and momentum transfer), or
7 is pumped in by external means, with flow being
8 induced around the housing 2 and also through the
9 passage 3 of the mist generator 1.

10

11 The convergent portion 58 of the casing 50 provides
12 a means of enhancing a momentum transfer (suction)
13 in mixing between the flow exiting the mist
14 generator 1 at exit 5 and the fluid drawn through
15 the casing 50. The enhanced suction and mixing of
16 the mist with the fluid drawn through the casing 50
17 could be used in such applications as gas cooling,
18 decontamination and gas scrubbing.

19

20 As an alternative to this specific configuration
21 shown in Fig. 14, inlet portion 52 may display a
22 shallow angle or indeed may be dimensionally
23 coincident with the bore of the central portion 56.
24 The outlet portion 58 may be of varied shape which
25 has different accelerative and mixing performance on
26 the spray cone angle and projection range on the
27 discharge of mist.

28

29 In a further embodiment of the present invention, as
30 shown in Fig. 15, there is no straight-through
31 passage 3 as with previous embodiments. Thus there

1 is no requirement for the introduction of the inlet
2 fluid (air).
3

4 In this embodiment the apparatus for generating a
5 mist (mist generator 1) comprises a conduit or
6 housing 2, providing a mixing chamber 9, a transport
7 fluid inlet 3, a working fluid inlet 4 and an outlet
8 or exit 5.
9

10 The transport fluid inlet 3 has an annular chamber
11 or plenum 8 provided in the housing 2, the inlet 3
12 also has a transport nozzle 16 for the introduction
13 of a transport fluid into the mixing chamber 9.
14

15 A protrusion 6 extends into the housing 2 and
16 defines a plenum 8 for the introduction of the
17 transport fluid into the mixing chamber 9 via the
18 transport nozzle 16.
19

20 A distal end 12 of the protrusion 6 is tapered on
21 its relatively outer surface 14 and defines the
22 transport nozzle 16 between it and a correspondingly
23 tapered part 18 of the housing 2.
24

25 The working fluid inlet 30 has a plenum 32 provided
26 in the housing 2, the working fluid inlet 30 also
27 has a working nozzle 34 formed at a location
28 coincident with that of the transport nozzle 16.
29

30 The transport nozzle 16 and working nozzle 34 are
31 substantially similar to that of previous
32 embodiments.

1
2 In operation the working fluid inlet 30 is connected
3 to a source of working fluid, water. The transport
4 fluid inlet 3 is connected to a source of transport
5 fluid, steam. Introduction of the steam into the
6 inlet 3, through the plenum 8, causes a jet of steam
7 to issue forth through the transport nozzle 16. The
8 parametric characteristics or properties of the
9 steam, for example, pressure, temperature, dryness
10 (quality), etc., are selected whereby in use the
11 steam issues from the transport nozzle 16 at
12 supersonic speeds into a mixing region of the
13 chamber 10, hereinafter described as the mixing
14 chamber 9. The steam jet issuing from the transport
15 nozzle 16 impacts the working fluid issuing from the
16 working nozzle 34 with high shear forces, thus
17 atomising the water into droplets and occasioning
18 induction of the resulting water mist through the
19 mixing chamber 9 towards the exit 5.

20
21 The parametric characteristics, i.e. the internal
22 geometries of the nozzles 16, 34 and their angular
23 orientation, the cross-section and length of the
24 mixing chamber, and the properties of the working
25 and transport fluids are modulated/manipulated to
26 discharge a water mist with a substantially uniform
27 droplet distribution having a substantial portion of
28 droplets with a size less than 50 μ m.

29
30 Fig. 16 shows yet a further embodiment of the
31 present invention similar to that illustrated in
32 Fig. 15 save that the protrusion 6 incorporates a

1 supplementary nozzle 22, which is axial to the
2 longitudinal axis of the housing 2 and which is in
3 fluid communication with the mixing chamber 9. An
4 inlet 3a is formed at a front end of the protrusion
5 6 (distal from the exit 5) extending into the
6 housing 2 incorporating interiorly thereof a plenum
7 7 for the introduction of the transport fluid,
8 steam. The plenum 7 is in fluid communication with
9 the plenum 8 through one or more channels 11.

10

11 A distal end 12 of the protrusion 6 remote from the
12 inlet 3A is tapered on its internal surface 20 and
13 defines a parallel axis aligned supplementary nozzle
14 22, the supplementary nozzle 22 being in fluid
15 communication with the plenum 7.

16

17 The supplementary nozzle 22 is so shaped as in use
18 to give supersonic flow of the transport fluid into
19 the mixing chamber 9. For a given steam condition,
20 i.e. dryness (quality), pressure and temperature,
21 the nozzle 22 is preferably configured to provide
22 the highest velocity steam jet, the lowest pressure
23 drop and the highest enthalpy between the plenum and
24 the transport nozzle exit. However, it is envisaged
25 that the flow of transport fluid into the mixing
26 chamber may alternatively be sub-sonic in some
27 applications as hereinbefore described.

28

29 The supplementary nozzle 22 has an area ratio in the
30 range 1.75 to 15 with an included angle (α) less
31 than 6 degrees for supersonic flow, and 12 degrees
32 for sub-sonic flow; although (α) may be higher.

1
2 It is to be appreciated that the supplementary
3 nozzle 22 is angled to provide the desired
4 interaction between the transport and working fluid
5 occasioning the optimum energy transfer by momentum
6 and mass transfer to obtain the required intensity
7 of shearing suitable for the required droplet size.
8 The supplementary nozzle 22 as shown in Fig. 16 may
9 be located off-centre and/or may be tilted.

10
11 In operation the working fluid inlet 30 is connected
12 to a source of the working fluid to be dispersed,
13 water. The fluid inlet 3a is connected to a source
14 of transport fluid, steam. Introduction of the
15 steam into the inlet 3a, through the plenums 7, 8
16 causes a jet of steam to issue forth through the
17 transport nozzle 16 and the supplementary nozzle 22.
18 The parametric characteristics or properties of the
19 steam are selected whereby in use the steam issues
20 from the nozzles at supersonic speeds into the
21 mixing chamber 9. The steam jets issuing from the
22 nozzles 16, 22 impact the working fluid issuing from
23 the working nozzle 34 with high shear forces, thus
24 atomising the water into droplets and occasioning
25 induction of the resulting water mist through the
26 mixing chamber 9 towards the exit 5.

27
28 The parametric characteristics, i.e. the internal
29 geometries of the nozzles 16, 34 and their angular
30 orientation, the cross-section (and length) of the
31 mixing chamber, and the properties of the working
32 and transport fluids are modulated/manipulated to

1 discharge a water mist with a substantially uniform
2 droplet distribution having a substantial portion of
3 droplets with a size less than 50 μ m.

4
5 It is to be appreciated that the supplementary
6 nozzle 22 will increase the turbulent break up, and
7 also influence the shape of the emerging mist plume.

8
9 The supplementary nozzle 22 may be incorporated into
10 any other embodiment of the present invention.

11
12 Fig. 17 shows an embodiment substantially similar to
13 that illustrated in Fig. 16 save that an additional
14 transport fluid inlet 40 and plenum 42 are provided
15 in the housing 2, together with a second transport
16 nozzle 44 formed at a location coincident with that
17 of the working nozzle 34, thus providing a co-
18 annular nozzle arrangement.

19
20 The transport nozzles 16, 44, the supplementary
21 nozzle 22 and the working nozzle 34 are angled to
22 provide the desired angles of interaction between
23 the steam and water, and optimum energy transfer by
24 momentum and mass transfer to enhance turbulence.

25
26 In operation the high velocity steam jets issuing
27 from the nozzles 16, 22, 44 impact the water with
28 high shear forces, thus breaking the water into fine
29 droplets and producing a well mixed two phase
30 condition constituted by the liquid phase of the
31 water and the steam. This both enhances the droplet
32 formation by providing a double shearing action, and

1 also provides a fluid separation or cushion between
2 the water and the internal walls 36 of the mixing
3 chamber 9. This prevents small water droplets being
4 lost through coalescence on the internal walls 36 of
5 the mixing chamber 9 before exiting the mist
6 generator 1 via the outlet 5. Additionally the
7 nozzles 16, 22, 44 are angled and shaped to provide
8 the desired droplet formation. In this instance,
9 the energy transfer mechanism of momentum and mass
10 transfer occasion's projection of the spray mist
11 through the mixing chamber 9 and out of the exit 5.

12
13 Fig. 18 shows an embodiment substantially similar to
14 that illustrated in Fig. 16 save that it is provided
15 with a diverging mixing chamber 9 and a radial
16 transport fluid inlet 3 rather than the parallel
17 axis inlet 3a shown in Fig. 16. However, either
18 inlet type may be used.

19
20 The transport nozzle 16, the supplementary nozzle 22
21 and the working nozzle 34 are angled to provide the
22 desired angles of interaction between the transport
23 and the working fluid occasioning the optimum energy
24 transfer by momentum and mass transfer to enhance
25 turbulence.

26
27 The arrangement illustrated provides a more diffuse
28 or wider spray cone angle and therefore a wider mist
29 coverage. The angle of the internal walls 36 of the
30 mixing chamber 9 relative to a longitudinal
31 centreline of the mist generator 1, and the angles
32 of the nozzles 16, 22, 34 relative to the walls 36,

1 may be varied to provide different droplet sizes,
2 droplet distributions, spray cone angles and
3 projection ranges. In an alternative embodiment,
4 not shown, the mixing chamber 9 may be converging.
5 This will provide a narrow concentrated mist spray,
6 and may provide a greater axial velocity for the
7 mist and therefore a greater projection range.

8
9 Fig. 19 shows a further embodiment of the present
10 invention substantially similar to the embodiment
11 illustrated in Fig. 18 save that an additional
12 transport fluid inlet 40 and plenum 42 are provided
13 in the housing 2, together with a second transport
14 nozzle 44 formed at a location coincident with that
15 of the working nozzle 34, thus providing a co-
16 annular nozzle arrangement.

17
18 This embodiment is provided with a diverging mixing
19 chamber section 9 and the nozzles 16, 22, 34, 44 are
20 also angled to provide the desired angles of
21 interaction between the transport and working fluid,
22 thus occasioning the optimum energy transfer by
23 momentum and mass transfer to enhance turbulence.

24
25 The arrangement illustrated provides a more diffuse
26 or wider spray cone angle and therefore a wider mist
27 coverage. The angle of the inner walls 36 of the
28 mixing chamber 9 relative to the longitudinal
29 centreline of the mist generator 1, and the angles
30 of the nozzles 16, 22, 34, 44 relative to the walls
31 36, may be varied to provide different droplet
32 sizes, droplet distributions, spray cone angles and

1 projection ranges. In an alternative embodiment,
2 not shown, the mixing chamber 9 may be converging.
3 This will provide a narrow concentrated mist spray,
4 and may provide a greater axial velocity for the
5 mist and therefore a greater projection range.
6
7 In operation the high velocity streams of steam
8 exiting their respective nozzles 16, 22, 44,
9 sandwich the water stream exiting the working nozzle
10 34. This both enhances the droplet formation by
11 providing a double shearing action, and also
12 provides a fluid separation or cushion between the
13 water and the walls 36 of the mixing chamber 9.
14 This prevents small water droplets being lost
15 through coalescence on the internal walls of the
16 mixing chamber 9 before exiting the mist generator
17 via the exit 5.
18
19 Referring now to Fig. 20, which shows a further
20 embodiment of an apparatus for generating a mist
21 (mist generator 1) comprising a conduit or housing
22 2, a transport fluid inlet 3a and plenum 7 provided
23 in the housing 2 for the introduction of the
24 transport fluid, steam, into a mixing chamber 9.
25 The mist generator 1 also comprises a protrusion 38
26 at the end of the plenum 7 which is tapered on its
27 relatively outer surface 40 and defines an annular
28 transport nozzle 16 between it and a correspondingly
29 tapered part 18 of the inner wall of the housing 2,
30 the transport nozzle 16 being in fluid communication
31 with the plenum 7.
32

1 The mist generator 1 includes a working fluid inlet
2 30 and plenum 32 provided in the housing 2, together
3 with a working nozzle 34 formed at a location
4 coincident with that of the transport nozzle 16.

5
6 This embodiment is provided with a diverging mixing
7 chamber section 9 and the transport nozzle 16 and
8 the working nozzle 34 are also angled to provide the
9 desired angles of interaction between the transport
10 and working fluid, thus occasioning the optimum
11 energy transfer by momentum and mass transfer to
12 enhance turbulence. The arrangement illustrated
13 provides a diffuse or wide spray cone angle and
14 therefore a wider mist coverage. The angle of the
15 internal walls 36 of the mixing chamber 9 relative
16 to the longitudinal centreline of the mist generator
17 1, and the angles of the nozzles 16, 34 relative to
18 the walls 36, may be varied to provide different
19 droplet sizes, droplet distributions, spray cone
20 angles and projection ranges. In an alternative
21 embodiment, not shown, the mixing chamber 9 may be
22 converging. This provides a narrow concentrated
23 mist spray, a greater axial velocity for the mist
24 spray and therefore a greater projection range.

25
26 Fig. 21 shows a further embodiment substantially
27 similar to that illustrated in Fig. 20 save that the
28 protrusion 38 incorporates a parallel axis aligned
29 supplementary nozzle 22, the nozzle 22 being in flow
30 communication with a plenum 7.

31

1 The supplementary nozzle 22 is substantially similar
2 to previous supplementary nozzles.

3
4 In operation the working fluid inlet 30 is connected
5 to a source of working fluid, water. The inlet 3a
6 is connected to a source of transport fluid, steam.
7 Introduction of the steam into the inlet 3a, through
8 the plenum 7 causes jets of steam to issue forth
9 through the nozzles 16, 22. The parametric
10 characteristics or properties of the steam are
11 selected whereby in use the steam issues from the
12 nozzles 16, 22 at supersonic speeds into the mixing
13 chamber 9. The steam jet issuing from the nozzle 16
14 impacts the working fluid issuing from the working
15 nozzle 34 with high shear forces, thus atomising the
16 water into droplets and occasioning induction of the
17 resulting water mist through the mixing chamber 9
18 towards an exit 5. The angle of the walls 36 of the
19 mixing chamber 9 relative to the longitudinal
20 centreline of the mist generator 1, and the angles
21 of the nozzles 16, 22, 34 relative to the walls 36,
22 may be varied to provide different droplet sizes,
23 droplet distributions, spray cone angles and
24 projection ranges.

25
26 It is to be appreciated that any feature or
27 derivative of the embodiments shown in Figs. 1 to 21
28 may be adopted or combined with one another to form
29 other embodiments.

30
31 It is also to be appreciated that whilst the
32 supplementary nozzles have been described in fluid

1 communication with the transport fluid, it is
2 anticipated that the supplementary nozzles may be
3 connected to a second transport fluid.

4

5 It is an advantage of the present invention that the
6 working nozzle(s) provides an annular flow having an
7 even distribution of working fluid around the
8 annulus.

9

10 With reference to the aforementioned embodiments of
11 the present invention, the parametric
12 characteristics or properties of the inlet, working
13 and transport fluids, for example the flow rate,
14 pressure, velocity, quality (e.g. dryness) and
15 temperature, can be regulated to give the required
16 intensity of shearing and droplet formation. The
17 properties of the inlet, working and transport
18 fluids being controllable by either external means,
19 such as a pressure regulation means, or by the gap
20 size (internal geometry) employed within the
21 nozzles.

22

23 Although Figs. 16, 17, 20, 21 illustrate the
24 transport fluid inlet 3a located in a parallel axis
25 to the longitudinal centreline of the mist generator
26 1, feeding transport fluid directly into plenum 7,
27 it is envisaged that the transport fluid may be
28 introduced through alternative locations, for
29 example through a radial inlet such as inlet 3 as
30 illustrated in Fig. 18, which in turn may feed
31 either or both plenums 7 and 8 directly, or through
32 an alternative parallel axis location feeding

1 directly into plenum 8 rather than plenum 7 (not
2 shown). Additionally the fluid inlet 30 may
3 alternatively be positioned in a parallel axis
4 location (not shown), feeding working fluid along
5 the housing to the plenum 32.

6
7 In all embodiments of the present invention, the
8 working nozzles may alternatively form the inlet for
9 other fluids, or solids in flowable form such as a
10 powder, to be dispersed for use in mixing or
11 treatment purposes. For example, a second working
12 nozzle may be provided to provide chemical treatment
13 of the working fluid, such as a fire retardant, if
14 necessary. The placement of the second working
15 nozzle may be either upstream or downstream of the
16 transport nozzle or where more than one transport
17 nozzle is provided, the placement may be both
18 upstream and downstream dependent upon requirements.

19
20 Referring to the embodiments shown in Figs. 1, 12 to
21 14, for using the mist generator 1 as a fire
22 suppressant in a room or other contained volume, the
23 mist generator 1 may be either located entirely
24 within the volume or room containing a fire, or
25 located such that only the exit 5 protrudes into the
26 volume. Consequently, the inlet fluid entering via
27 inlet 4 may either be the gasses already within the
28 room, these may range from cold gasses to hot
29 products of combustion, or may be a separate fluid
30 supply, for example air or an inert gas from outside
31 the room. In the situation where the mist generator
32 1 is located entirely within the room, the induced

1 flow through the passage 3 of the mist generator 1
2 may induce smoke and other hot combustion products
3 to be drawn into the inlet 4 and be intimately mixed
4 with the other fluids within the mist generator.
5 This will increase the wetting and cooling effect on
6 these gases and particles. It is also to be
7 appreciated that the actual cooling mist will
8 increase the wetting and cooling effect on the
9 gasses and particles too.

10

11 Generating and introducing water mist containing a
12 large amount of air into a potentially explosive
13 environment such as a combustible gas filled room
14 will result in both the reduction of risk of
15 ignition from the water mist plus the dilution of
16 the gas to a safe gas/oxygen ratio from the air.

17

18 If a fire in a contained volume has burnt most of
19 the available oxygen, a water mist may be introduced
20 but with the flow of air stopped. This helps to
21 extinguish the remaining fire without the risk of
22 adding more oxygen. To this end, the flow of the
23 inlet fluid (air) through the inlet 4 may be
24 controllable by restricting or even closing the
25 inlet 4 completely. This could be accomplished by
26 using a control valve. Alternatively, the
27 embodiments shown in Figs. 15 to 21 may be used in
28 this scenario.

29

30 In a modification, an inert gas may be used as the
31 inlet fluid in place of air, or, with regard to
32 using the embodiments shown in Figs. 15 to 21, a

1 further working nozzle may be added to introduce an
2 inert gas or non-flammable fluid to suppress the
3 fire.

4
5 Similarly, powders or other particles may be
6 entrained or introduced into the mist generator,
7 mixed with and dispersed with another fluid or
8 fluids. The particles being dispersed with the
9 other fluid or fluids, or wetted and/or coated or
10 otherwise treated prior to being projected.

11
12 The mist generator of the present invention has a
13 number of fundamental advantages over conventional
14 water mist systems in that the mechanism of droplet
15 formation and size is controlled by a number of
16 adjustable parameters, for example, the flow rate,
17 pressure, velocity, quality and temperature of the
18 inlet, transport and working fluid; the angular
19 orientation and internal geometry of the transport,
20 supplementary and working nozzles; the cross-
21 sectional area and length of the mixing chamber 3A.
22 This provides active control over the amount of
23 water used, the droplet size, the droplet
24 distribution, the spray cone angle and the projected
25 range (distance) of the mist. For example, a water
26 mist generator using steam as the transport fluid
27 can produce a water mist with a substantially
28 uniform droplet distribution having a substantial
29 portion of droplets with a size less than 50 μ m, with
30 an adjustable spray cone angle and projected range
31 of over 40 meters.

32

1 A key advantage of the present invention is that the
2 uniform droplets formed, which have a substantial
3 portion of droplets with a size less than 50 μ m, have
4 sufficient momentum, because of the momentum
5 transfer, to project a sufficient distance and also
6 penetrate into the heat of a fire, which is distinct
7 with the prior art where droplet sizes less than
8 40 μ m will have insufficient momentum to project a
9 sufficient distance and also penetrate into the heat
10 of a fire.

11
12 A major advantage of the present invention is its
13 ability to handle relatively more viscous working
14 fluids and inlet fluids than conventional systems.
15 The shocks and the momentum transfer that takes
16 place provide suction causing the mist generator to
17 act like a pump. Also, the shearing effect and
18 turbulence of the high velocity steam jet breaks up
19 the viscous working fluid and mixes it, making it
20 less viscous.

21
22 The mist generator can be used for either short
23 burst operation or continuous or pulsed
24 (intermittent) or discontinuous running.

25
26 As there are no moving parts in the system and the
27 mist generator is not dependent on small sized and
28 closely toleranced fluid inlet nozzles, there is
29 very little maintenance required. It is known that
30 due to the small orifice size and high water
31 pressures used by some of the existing water mist

1 systems, that nozzle wear is a major issue with
2 these systems.

3

4 In addition, due to the use of relatively large
5 fluid inlets in the mist generator it is less
6 sensitive to poor water quality. In cases where the
7 mist generator is to be used in a marine
8 environment, even sea water may be used.

9

10 Although the mist generator may use a hot
11 compressible transport fluid such as steam, this
12 system is not to be confused with existing steam
13 flooding systems which produce a very hot
14 atmosphere. In the current invention, the heat
15 transfer between the steam and the working fluid
16 results in a relatively low water mist temperature.
17 For example, the exit temperature within the mist at
18 the point of exit 5 has been recorded at less than
19 52°C, reducing through continued heat transfer
20 between the steam and water to room temperature
21 within a short distance. The exit temperature of
22 the discharge of water mist is controllable by
23 regulation of the steam supply conditions, i.e. flow
24 rate, pressure, velocity, temperature, etc., and the
25 water flow rate conditions, i.e. flow rate,
26 pressure, velocity, and temperature, and the inlet
27 fluid conditions.

28

29 Droplet formation within the mist generator may be
30 further enhanced with the entrainment of chemicals
31 such as surfactants. The surfactants can be
32 entrained directly into the mist generator and

1 intimately mixed with the working fluid at the point
2 of droplet formation, thereby minimising the
3 quantity of surfactant required.

4

5 It is an advantage of the straight-through passage
6 of the mist generator, and the relatively large
7 inlet nozzle geometries, that it can accommodate
8 material that might find its way into the passage.

9 It is a feature of the present invention that it is
10 far more tolerant of the water quality used than
11 conventional water mist systems which depend on
12 small orifices and close tolerance nozzles.

13

14 The ability of the mist generator to handle and
15 process a range of working fluids provides
16 advantages over many other mist generators. As the
17 desired droplet size is achieved through high
18 velocity shear and, in the case of steam as the
19 transport fluid, mass transfer from a separate
20 transport fluid, almost any working fluid can be
21 introduced to the mist generator to be finely
22 dispersed and projected. The working fluids can
23 range from low viscosity easily flowable fluids and
24 fluid/solid mixtures to high viscosity fluids and
25 slurries. Even fluids or slurries containing
26 relatively large solid particles can be handled.

27

28 It is this versatility that allows the present
29 invention to be applied in many different
30 applications over a wide range of operating
31 conditions. Furthermore the shape of the mist
32 generator may be of any convenient form suitable for

1 the particular application. Thus the mist generator
2 may be circular, curvilinear or rectilinear, to
3 facilitate matching of the mist generator to the
4 specific application or size scaling.

5

6 The present invention thus affords wide
7 applicability with improved performance over the
8 prior art proposals in the field of water mist
9 generators.

10

11 In some embodiments of the present invention a
12 series of transport nozzles and working nozzles is
13 provided lengthwise of the passage and the geometry
14 of the nozzles may vary from one to the other
15 dependent upon the effect desired. For example, the
16 angular orientation may vary one to the other. The
17 nozzles may have differing geometries in order to
18 afford different effects, i.e. different performance
19 characteristics, with possibly differing parametric
20 steam conditions. For example, some nozzles may be
21 operated for the purpose of initial mixing of
22 different liquids and gases whereas others are used
23 simultaneously for additional droplet break-up or
24 flow directionalisation. Each nozzle may have a
25 mixing chamber section downstream thereof. In the
26 case where a series of nozzles is provided the
27 number of operational nozzles is variable.

28

29 The mist generator of the present invention may be
30 employed in a variety of applications ranging from
31 fire extinguishing, suppression or control to smoke
32 or particle wetting.

1
2 Due to the relatively low pressures involved in the
3 present invention, the mist generator can be easily
4 relocated and re-directed while in operation. Using
5 appropriate flexible steam and water supply pipes
6 the mist generator is easily man portable. The unit
7 can be considered portable from two perspectives.
8 Firstly the transport nozzle(s) can be moved
9 anywhere only constrained by the steam and water
10 pipe lengths. This may have applications for fire
11 fighting or decontamination when the nozzle can be
12 man-handled to specific areas for optimum coverage
13 of the mist. This 'umbilical' approach could be
14 extended to situations where the nozzle is moved by
15 a robotic arm or a mechanised system, being operated
16 remotely. This may have applications in very
17 hazardous environments.
18
19 Secondly, the whole system could be portable, i.e.
20 the nozzle, a steam generator, plus a water/chemical
21 supply is on a movable platform (e.g., self
22 propelled vehicle). This would have the benefits of
23 being unrestricted by any umbilical pipe lengths.
24 The whole system could possibly utilise a back-pack
25 arrangement.
26
27 The present invention may also be used for mixing,
28 dispersion or hydration and again the shearing
29 mechanism provides the mechanism for achieving the
30 desired result. In this connection the mist
31 generator may be used for mixing one or more fluids,
32 one or more fluids and solids in flowable or

1 particulate form, for example powders. The fluids
2 may be in liquid or gaseous form. This mechanism
3 could be used for example in the fighting of forest
4 fires, where powders and other additives, such as
5 fire suppressants, can be entrained, mixed and
6 dispersed with the mist spray.

7
8 In this area of usage lies another potential
9 application in terms of foam generation for fire
10 fighting purposes. The separate fluids, for example
11 water, a foaming agent, and possibly air, are mixed
12 within the mist generator using the transport fluid,
13 for example steam, by virtue of the shearing effect.

14
15 Additionally, in fire or other high temperature
16 environments the high density fine droplet mist
17 generated by the mist generator provides a thermal
18 barrier for people and fuel. In addition to
19 reducing heat transfer by convection and conduction
20 by cooling the air and gasses between the heat
21 source and the people or fuel, the dense mist also
22 reduces heat transfer by radiation. This has
23 particular, but not exclusive, application to fire
24 and smoke suppression in road, rail and air
25 transport, and may greatly enhance passenger post-
26 crash survivability.

27
28 The fine droplet mist generated by the present
29 invention may be employed for general cooling
30 applications. The high cooling rate and low water
31 quantities used provide the mechanism for cooling of
32 industrial machinery and equipment. For example,

1 the fine droplet mist has particular application for
2 direct droplet cooling of gas turbine inlet air.
3 The fine droplet mist, typically a water mist, is
4 introduced into the inlet air of the gas turbine and
5 due to the small droplet size and large evaporative
6 surface area, the water mist evaporates, cooling
7 the inlet air. The cooling of the inlet air boosts
8 the power of the gas turbine when it is operating in
9 hot environments.

10
11 Also, the very fine droplet mist produced by the
12 mist generator may be utilised for cooling and
13 humidifying area or spaces, either indoors or
14 outdoors, for the purpose of providing a more
15 habitable environment for people and animals.

16
17 The mist generator may be employed either indoors or
18 outdoors for general watering applications, for
19 example, the watering of the plants inside a
20 greenhouse. The water droplet size and distribution
21 may be controlled to provide the appropriate
22 watering mechanism, i.e. either root or foliage
23 wetting, or a combination of both. In addition, the
24 humidity of the greenhouse may also be controlled
25 with the use of the mist generator.

26
27 The mist generator may be used in an explosive
28 atmosphere to provide explosion prevention. The
29 mist cools the atmosphere and dampens any airborne
30 particulates, thus reducing the risk of explosion.
31 Additionally, due to the high cooling rate and wide
32 droplet distribution afforded by the fine droplet

1 mist the mist generator may be employed for
2 explosion suppression, particularly in a contained
3 volume. The mist generator has a further advantage
4 for use in potentially explosive atmospheres as it
5 has no moving parts or electrical wires or circuitry
6 and therefore has minimum sources of ignition.

7
8 A fire within a contained room will generally
9 produce hot gasses which rise to the ceiling. There
10 is therefore a temperature gradient formed with high
11 temperatures at or near the ceiling and lower
12 temperatures towards the floor. In addition, the
13 gasses produced will generally become stratified
14 within the room at different heights. An advantage
15 of the present invention is that the turbulence and
16 projection force of the mist helps to mix the gasses
17 within the room, mixing the high temperature gasses
18 with the low temperature gasses, thus reducing the
19 hot spot temperatures of the room.

20
21 This mixing of the room's gasses, and the turbulent
22 mist itself, which behaves more akin to a gas cloud,
23 is able to reach non line-of-sight areas, so
24 eliminating all hot spots (pockets of hot gasses)
25 and possible re-ignition zones. A further advantage
26 of the present invention is that the smaller water
27 droplets have more of a tendency to remain airborne,
28 thereby cooling the gases and the combustion
29 products of the fire. This improves the rate of
30 cooling of the fire and also reduces damage to items
31 in the vicinity of the fire.

32

1 The turbulence and projection force of the mist
2 allows for substantially all of the surfaces in the
3 room to be cooled or decontaminated, even the non
4 line of sight surfaces.

5
6 In addition, the turbulence and projection force of
7 the mist cause the water droplets to become attached
8 to hygroscopic nuclei suspended in the gasses,
9 causing the nuclei to become heavier and fall to the
10 floor, where they are more manageable; particularly
11 in decontamination applications. The water droplets
12 generated by the present invention have more of a
13 tendency to become attached to the nuclei by virtue
14 of their smaller size.

15
16 The mist generator may be used to deliberately
17 create hygroscopic nuclei within the room for the
18 purpose outlined above.

19
20 Due to the particle wetting of the gasses in a
21 contained volume by the mist generator and the
22 turbulence created within the apparatus and by the
23 cooling mist itself, pockets of gas are dispersed,
24 thereby limiting the chance of explosion.

25
26 The present invention has the additional benefit of
27 wetting or quenching of explosive or toxic
28 atmospheres utilising either just the steam, or with
29 additional entrained water and/or chemical
30 additives. The later configuration could be used for
31 placing the explosive or toxic substances in
32 solution for safe disposal.

1
2 Using a hot compressible transport fluid, such as
3 steam, may provide an additional advantage of
4 providing control of harmful bacteria. The shearing
5 mechanism afforded by the present invention coupled
6 with the heat input of the steam destroys the
7 bacteria in the fluid flow, thereby providing for
8 the sterilisation of the working fluid. The
9 sterilisation effect could be enhanced further with
10 the entrainment of chemicals or other additives
11 which are mixed into the working fluid. This may
12 have particular advantage in applications such as
13 fire fighting, where the working fluid, such as
14 water, is advantageously required to be stored for
15 some time prior to use. During operation, the mist
16 generator effectively sterilises the water,
17 destroying bacterium such as legionella pneumophila,
18 during the droplet creation phase, prior to the
19 water mist being projected from the mist generator.
20
21 The fine droplet mist produced by the mist generator
22 might be advantageously employed where there has
23 been a leakage or escape of chemical or biological
24 materials in liquid or gaseous form. The atomised
25 spray provides a mist which effectively creates a
26 blanket saturation of the prevailing atmosphere
27 giving a thorough wetting result. In the case where
28 chemical or biological materials are involved, the
29 mist wets the materials and occasions their
30 precipitation or neutralisation, additional
31 treatment could be provided by the introduction or
32 entrainment of chemical or biological additives into

1 the working fluid. For example disinfectants may be
2 entrained or introduced into the mist generator, and
3 introduced into a room to be disinfected in a mist
4 form. For decontamination applications, such as
5 animal decontamination or agricultural
6 decontamination, no premix of the chemicals is
7 required as the chemicals can be entrained directly
8 into the unit and mixed simultaneously. This
9 greatly reduces the time required to start
10 decontamination and also eliminates the requirement
11 for a separate mixer and holding tank.

12
13 The mist generator may be deployed as an extractor
14 whereby the injection of the transport fluid, for
15 example steam, effects induction of a gas for
16 movement from one zone to another. One example of
17 use in this way is to be found in fire fighting when
18 smoke extraction at the scene of a fire is required.

19
20 Further the mist generator may be employed to
21 suppress or dampen down particulates from a gas.
22 This usage has particular, but not exclusive,
23 application to smoke and dust suppression from a
24 fire. Additional chemical additives in fluid and/or
25 powder form may be entrained and mixed with the flow
26 for treatment of the gas and/or particulates.

27
28 Further the mist generator for scrubbing particulate
29 materials from a gas stream, to effect separation of
30 wanted elements from waste elements. Additional
31 chemical additives in fluid and/or powder form may
32 be entrained and mixed with the flow for treatment

1 of the gas and/or particulates. This usage has
2 particular, but not exclusive, application to
3 industrial exhaust scrubbers and dust extraction
4 systems.

5
6 The use of the mist generator is not limited to the
7 creation of water droplet mists. The mist generator
8 may be used in many different applications which
9 require a fluid to be broken down into a fine
10 droplet mist. For example, the mist generator may
11 be used to atomise a fuel, such as fuel oil, for the
12 purpose of enhancing combustion. In this example,
13 using steam as the transport fluid and a liquid fuel
14 as the working fluid produces a finely dispersed
15 mixture of fine fuel droplets and water droplets.
16 It is well known in the art that such mixtures when
17 combined with oxygen provides for enhanced
18 combustion. In this example, the oxygen, possibly
19 in the form of air, could also be entrained, mixed
20 with and projected with the fuel/steam mist by the
21 mist generator. Alternatively, a different
22 transport fluid could be used and water or another
23 fluid can be entrained and mixed with the fuel
24 within the mist generator.

25
26 Alternatively, using a combustible fuel and air as
27 the working fluids, but with a source of ignition at
28 the exit of the unit, the mist generator may be
29 employed as a space heater.

30
31 Further, the mist generator may be employed as an
32 incinerator or process heater. In this example, a

1 combustible fluid, for example propane, may be used
2 as the transport fluid, introduced to the mist
3 generator under pressure. In this example the
4 working fluid may be an additional fuel or material
5 which is required to be incinerated. Interaction
6 between the transport fluid and working fluid
7 creates a well mixed droplet mist which can be
8 ignited and burnt in the mixing chamber or a
9 separate chamber immediately after the exit.
10 Alternatively, the transport fluid can be ignited
11 prior to exiting the transport nozzles, thereby
12 presenting a high velocity and high temperature
13 flame to the working fluid.

14
15 The mist generator affords the ability to create
16 droplets created of a multi fluid emulsion. The
17 droplets may comprise a homogeneous mix of different
18 fluids, or may be formed of a first fluid droplet
19 coated with an outer layer or layers of a second or
20 more fluids. For example, the mist generator may be
21 employed to create a fuel/water emulsion droplet
22 mist for the purpose of further enhancing
23 combustion. In this example, the water may either
24 be separately entrained into the mist generator, or
25 provided by the transport fluid itself, for example
26 from the steam condensing upon contact with the
27 working fluid. Additionally, the oxygen required
28 for combustion, possibly in the form of air, could
29 also be entrained, mixed with and projected with the
30 fuel/steam mist by the generator.

31

1 The mist generator may be employed for low pressure
2 impregnation of porous media. The working fluid or
3 fluids, or fluid and solids mixtures being dispersed
4 and projected onto a porous media, so aiding the
5 impregnation of the working fluid droplets into the
6 material.

7
8 The mist generator may be employed for snow making
9 purposes. This usage has particular but not
10 exclusive application to artificial snow generation
11 for both indoor and outdoor ski slopes. The fine
12 water droplet mist is projected into and through the
13 cold air whereupon the droplets freeze and form a
14 frozen droplet 'snow'. This cooling mechanism may
15 be further enhanced with the use of a separate
16 cooler fitted at the exit of the mist generator to
17 enhance the cooling of the water mist. The
18 parametric conditions of the mist generator and the
19 transport fluid and working fluid properties and
20 temperatures are selected for the particular
21 environmental conditions in which it is to operate.
22 Additional fluids or powders may be entrained and
23 mixed within the mist generator for aiding the
24 droplet cooling and freezing mechanism. A cooler
25 transport fluid than steam could be used.

26
27

28 The high velocity of the water mist spray may
29 advantageously be employed for cutting holes in
30 compacted snow or ice. In this application the
31 working fluid, which may be water, may
32 advantageously be preheated before introduction to

1 the mist generator to provide a higher temperature
2 droplet mist. The enhanced heat transfer with the
3 impact surface afforded by the water being in a
4 droplet form, combined with the high impact velocity
5 of the droplets provide a melting/cutting through
6 the compacted snow or ice. The resulting waste
7 water from this cutting operation is either driven
8 by the force of the issuing water mist spray back
9 out through the hole that has been cut, or in the
10 case of compacted snow may be driven into the
11 permeable structure of the snow. Alternatively,
12 some or all of the waste water may be introduced
13 back into the mist generator, either by entrainment
14 or by being pumped, to provide or supplement the
15 working fluid supply. The mist generator may be
16 moved towards the 'cutting face' of the holes as the
17 depth of the hole increases. Consequently, the
18 transport fluid and the water may be supplied to the
19 mist generator co-axially, to allow the feed supply
20 pipes to fit within the diameter of the hole
21 generated. The geometry of the nozzles, the mixing
22 chamber and the outlet of the mist generator, plus
23 the properties of the transport fluid and working
24 fluid are selected to produce the required hole size
25 in the snow or ice, and the cutting rate and water
26 removal rate.

27
28 Modifications may be made to the present invention
29 without departing from the scope of the invention,
30 for example, the supplementary nozzle, or other
31 additional nozzles, could be used in the form of
32 NACA ducts, which are used to bleed high pressure

1 from a high pressure surface to a low pressure
2 surface to maintain the boundary layer on the
3 surfaces and reduce drag.

4
5 The NACA ducts may be employed on the mist generator
6 1 from the perspective of using drillings through
7 the housing 2 to feed a fluid to a wall surface
8 flow. For example, additional drillings could be
9 employed to simply feed air or steam through the
10 drillings to increase the turbulence in the mist
11 generator and increase the turbulent break up. The
12 NACA ducts may also be angled in such a way to help
13 directionalise the mist emerging from the mist
14 generator. Holes or even an annular nozzle may be
15 situated on the trailing edge of the mist generator
16 to help to force the exiting mist to continue to
17 expand and therefore diffuse the flow (an exiting
18 high velocity flow will tend to want to converge).

19
20 NACA ducts could be employed, depending on the
21 application, by using the low pressure area within
22 the mist generator to draw in gasses from the
23 outside surface to enhance turbulence. NACA ducts
24 may have applications in situations where it is
25 beneficial to draw in the surrounding gasses to be
26 processed with the mist generator, for example,
27 drawing in hot gasses in a fire suppression role may
28 help to cool the gasses and circulate the gasses
29 within the room.

30
31 Enhancing turbulence in the mist generator helps to
32 both increase droplet formation (with smaller

1 droplets) and also the turbulence of the generated
2 mist. This has benefits in fire suppression and
3 decontamination of helping to force the mist to mix
4 within the mist generator and wet all surfaces
5 and/or mix with the hot gasses.. In addition to the
6 aforesaid, turbulence may be induced by the use of
7 guide vanes in either the nozzles or the passage.
8 Turbulators may be helical in form or of any other
9 form which induces swirl in the fluid stream.

10

11 As well as turbulators increasing turbulence, they
12 will also reduce the risk of coalescence of the
13 droplets on the turbulator vanes/blades.

14

15 The turbulators themselves could be of several
16 forms, for example, surface projections into the
17 fluid path, such as small projecting vanes or nodes;
18 surface grooves of various profiles and orientations
19 as shown in Figs 5 to 10; or larger systems which
20 move or turn the whole flow - these may be angled
21 blades across the whole bore of the flow, of either
22 a small axial length or of a longer 'Archimedes type
23 design. In addition, elbows of varying angles
24 positioned along various planes may be used to induce
25 swirl in the flow streams before they enter their
26 respective inlets.

27

28 It is anticipated that the mist generator may
29 include piezoelectric or ultrasonic actuators that
30 vibrate the nozzles to enhance droplet break up.

1 **Claims**

2

3 1. Apparatus for generating a mist comprising:
4 a conduit having a mixing chamber and an exit;
5 a transport nozzle in fluid communication with
6 the said conduit, the transport nozzle being adapted
7 to introduce a transport fluid into the mixing
8 chamber;

9 a working nozzle positioned adjacent the
10 transport nozzle intermediate the transport nozzle
11 and the exit, the working nozzle being adapted to
12 introduce a working fluid into the mixing chamber;
13 the transport and working nozzles having an
14 angular orientation and internal geometry such that
15 in use interaction of the transport fluid and
16 working fluid in the mixing chamber causes the
17 working fluid to atomise and form a dispersed
18 vapour/droplet flow regime, which is discharged as a
19 mist from the exit, the mist comprising working
20 fluid droplets having a substantially uniform size.

21

22 2. The apparatus of claim 1, wherein the transport
23 and/or working nozzle substantially circumscribes
24 the conduit.

25

26 3. The apparatus of claim 1 or 2, wherein the
27 angular orientation and internal geometry of the
28 transport and working nozzles is such that the size
29 of the working fluid droplets is less than 50µm.

30

31 4. The apparatus of any preceding claim, wherein
32 the mixing chamber includes a converging portion.

1

2 5. The apparatus of any of claims 1 to 3, wherein
3 the mixing chamber includes a diverging portion.

4

5 6. The apparatus of any preceding claim, wherein
6 the apparatus includes a second transport nozzle
7 being adapted to introduce further transport fluid
8 or a second transport fluid into the mixing chamber.

9

10 7. The apparatus of claim 7, wherein the second
11 transport nozzle is positioned nearer to the exit
12 than the working nozzle, such that the working
13 nozzle is intermediate both transport nozzles.

14

15 8. The apparatus of any preceding claim, wherein
16 the mixing chamber includes an inlet adapted to
17 introduce an inlet fluid into the mixing chamber,
18 the inlet being distal from the exit, the transport
19 and working nozzles being arranged intermediate the
20 inlet and exit.

21

22 9. The apparatus of any preceding claim, wherein
23 the apparatus includes a supplementary nozzle
24 arranged inside the transport nozzle and adapted to
25 introduce further transport fluid or a second
26 transport fluid into the mixing chamber.

27

28 10. The apparatus of claim 9, wherein the
29 supplementary nozzle is arranged axially in the
30 mixing chamber.

31

- 1 11. The apparatus of claim 9 or 10, wherein the
2 supplementary nozzle extends forward of the
3 transport nozzle.
4
- 5 12. The apparatus of any of claims 9 to 11, wherein
6 the supplementary nozzle is shaped with a
7 convergent-divergent profile to provide supersonic
8 flow of the transport fluid which flows
9 therethrough.
10
- 11 13. The apparatus of any preceding claim, wherein
12 the transport nozzle is shaped such that the
13 transport fluid introduced into the mixing chamber
14 through the transport nozzle has a divergent or
15 convergent flow pattern.
16
- 17 14. The apparatus of claim 13, wherein the
18 transport nozzle has inner and outer surfaces each
19 being substantially frustoconical in shape.
20
- 21 15. The apparatus of any preceding claim, wherein
22 the working nozzle is shaped such that working fluid
23 introduced into the mixing chamber through the
24 working nozzle has a convergent or divergent flow
25 pattern.
26
- 27 16. The apparatus of claim 15, wherein the working
28 nozzle has inner and outer surfaces each being
29 substantially frustoconical in shape.
30
- 31 17. The apparatus of any preceding claim, further
32 including control means adapted to control one or

1 more of droplet size, droplet distribution, spray
2 cone angle and projection distance.

3

4 18. The apparatus of any preceding claim, further
5 including control means to control one or more of
6 the flow rate, pressure, velocity, quality, and
7 temperature of the working or transport fluids.

8

9 19. The apparatus of claim 17 or claim 18, wherein
10 the control means includes means to control the
11 angular orientation and internal geometry of the
12 transport and working nozzles.

13

14 20. The apparatus of any of claims 17 to 19,
15 wherein the control means includes means to control
16 the internal geometry of at least part of the mixing
17 chamber or exit to vary it between convergent and
18 divergent.

19

20 21. The apparatus of any preceding claim, wherein
21 the internal geometry of the transport nozzles has
22 an area ratio, namely exit area to throat area, in
23 the range 1.75 to 15, having an included angle α
24 substantially equal to or less than 6 degrees for
25 supersonic flow and substantially equal to or less
26 than 12 degrees for sub-sonic flow.

27

28 22. The apparatus of any preceding claim, wherein
29 the transport nozzle is oriented at an angle β of
30 between 0 to 30 degrees.

31

1 23. The apparatus of any preceding claim, wherein
2 the mixing chamber is closed upstream of the
3 transport nozzle.
4

5 24. The apparatus of any preceding claim, wherein
6 the exit of the apparatus is provided with a cowl to
7 control the mist.
8

9 25. The apparatus of claim 24, wherein the cowl
10 comprises a plurality of separate sections arranged
11 radially, each section adapted to control and re-
12 direct a portion of the discharge of mist emerging
13 from the exit.
14

15 26. The apparatus of any preceding claim, wherein
16 the apparatus for generating a mist is located
17 within a further cowl.
18

19 27. The apparatus of any preceding claim, wherein
20 the conduit includes a passage.
21

22 28. The apparatus of any preceding claim, wherein
23 at least one of the passage, the transport
24 nozzle(s), working nozzle(s) and secondary nozzle(s)
25 has a turbulator to induce turbulence of the fluid
26 therethrough prior to the fluid being introduced
27 into the mixing chamber.
28

29 29. A spray system comprising apparatus of any of
30 claims 1 to 28 and transport fluid in the form of
31 steam.
32

1 30. The spray system of claim 29, further including
2 working fluid in the form of water.

3
4 31. The spray system of claim 29 or 30, further
5 including a steam generator and water supply.

6
7 32. The spray system of claim 31, wherein the spray
8 system is portable.

9
10 33. A method of generating a mist comprising the
11 steps of:

12 providing apparatus for generating a mist
13 comprising a transport and working nozzle and a
14 conduit, the conduit having a mixing chamber and an
15 exit;

16 introducing a stream of transport fluid into
17 the mixing chamber through the transport nozzle;

18 introducing a working fluid into the mixing
19 chamber through the working nozzle downstream of the
20 transport nozzle nearer to the exit;

21 atomising the working fluid by interaction of
22 the transport fluid with the working fluid to form a
23 dispersed vapour/droplet flow regime; and

24 discharging the dispersed vapour/droplet flow
25 regime through the exit as a mist comprising working
26 fluid droplets of substantially uniform size.

27
28 34. The method of claim 33, wherein the apparatus
29 is an apparatus according to any of claims 1 to 32.

30

1 35. The method of claim 33 or 34, wherein the
2 stream of transport fluid introduced into the mixing
3 chamber is annular.

4
5 36. The method of any of claims 33 to 35, wherein
6 the working fluid droplets have a size less than
7 50 μ m.

8
9 37. The method of any of claims 33 to 36, wherein
10 the method includes the step of introducing the
11 transport fluid into the mixing chamber in a
12 continuous or discontinuous or intermittent or
13 pulsed manner.

14
15 38. The method of any of claims 33 to 37, wherein
16 the method includes the step of introducing the
17 transport fluid into the mixing chamber as a
18 supersonic flow.

19
20 39. The method of any of claims 33 to 38, wherein
21 the method includes the step of introducing the
22 working fluid into the mixing chamber in a
23 continuous or discontinuous or intermittent or
24 pulsed manner.

25
26 40. The method of any of claims 33 to 39, wherein
27 the method includes the step of introducing the
28 transport fluid into the mixing chamber as a sub-
29 sonic flow.

30

1 41. The method of any of claims 33 to 40, wherein
2 the mist is controlled by modulating at least one of
3 the following parameters:

4 the flow rate, pressure, velocity, quality
5 and/or temperature of the transport fluid;

6 the flow rate, pressure, velocity, quality
7 and/or temperature of the working fluid;

8 the flow rate, pressure, velocity, quality
9 and/or temperature of the inlet fluid;

10 the angular orientation of the transport and/or
11 working and/or secondary nozzle(s) of the apparatus;

12 the internal geometry of the transport and/or
13 working and/or secondary nozzle(s) of the apparatus;
14 and

15 the internal geometry, length and/or cross
16 section of the mixing chamber.

17
18 42. The method of any of claims 33 to 41, including
19 mixing the transport and working fluid together by
20 means of a high velocity transport fluid jet issuing
21 from the transport nozzle.

22
23 43. The method of any of claims 33 to 42, including
24 the generation of condensation shocks and/or
25 momentum transfer to provide suction within the
26 apparatus.

27
28 44. The method of any of claims 33 to 43, including
29 inducing turbulence of the inlet fluid prior to it
30 being introduced into the mixing chamber.

31

- 1 45. The method of any of claims 33 to 44, including
2 inducing turbulence of the working fluid prior to it
3 being introduced into the mixing chamber.
4
- 5 46. The method of any of claims 33 to 45 including
6 inducing turbulence of the transport fluid prior to
7 it being introduced into the mixing chamber.
8
- 9 47. The method of any of claims 33 to 46, wherein
10 the transport fluid is steam or an air/steam
11 mixture.
12
- 13 48. The method of any of claims 33 to 47, wherein
14 the working fluid is water or a water-based liquid.
15
- 16 49. The method of any of claims 33 to 48, wherein
17 the mist is used for fire suppression.
18
- 19 50. The method of any of claims 33 to 49, wherein
20 the mist is used for decontamination.
21
- 22 51. The method of any of claims 33 to 50, wherein
23 the mist is used for gas scrubbing.

1 **Abstract**

2

3 Apparatus for generating a mist comprising a conduit
4 having a mixing chamber and an exit; a transport
5 nozzle in fluid communication with the said conduit,
6 the transport nozzle being adapted to introduce a
7 transport fluid into the mixing chamber; a working
8 nozzle positioned adjacent the transport nozzle
9 intermediate the transport nozzle and the exit, the
10 working nozzle being adapted to introduce a working
11 fluid into the mixing chamber; the transport and
12 working nozzles having an angular orientation and
13 internal geometry such that in use interaction of
14 the transport fluid and working fluid in the mixing
15 chamber causes the working fluid to atomise and form
16 a dispersed vapour/droplet flow regime, which is
17 discharged as a mist from the exit, the mist
18 comprising working fluid droplets having a
19 substantially uniform size. A method of generating
20 a mist comprising the steps of providing apparatus
21 for generating a mist comprising a transport and
22 working nozzle and a conduit, the conduit having a
23 mixing chamber and an exit; introducing a stream of
24 transport fluid into the mixing chamber through the
25 transport nozzle; introducing a working fluid into
26 the mixing chamber through the working nozzle
27 downstream of the transport nozzle nearer to the
28 exit; atomising the working fluid by interaction of
29 the transport fluid with the working fluid to form a
30 dispersed vapour/droplet flow regime; and
31 discharging the dispersed vapour/droplet flow regime

80

- 1 through the exit as a mist comprising working fluid
- 2 droplets of substantially uniform size.

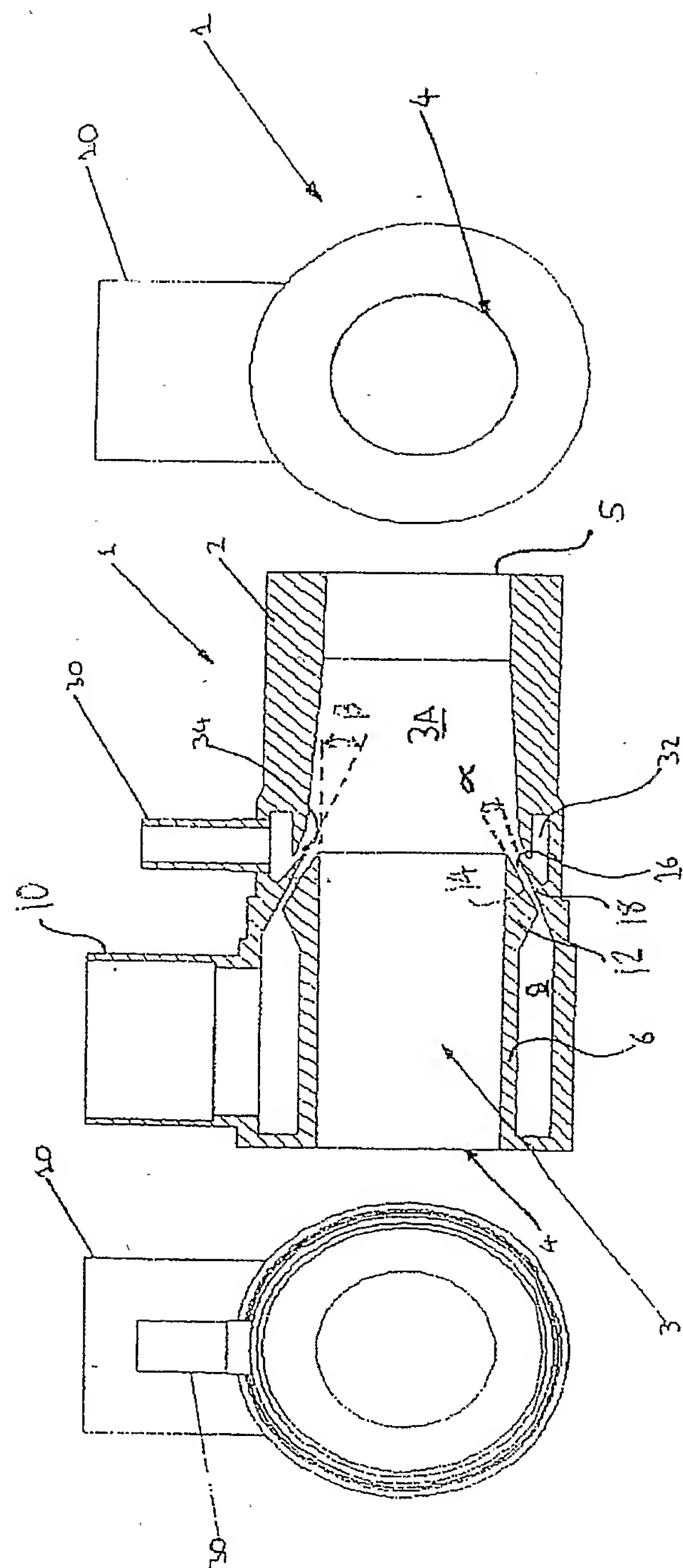
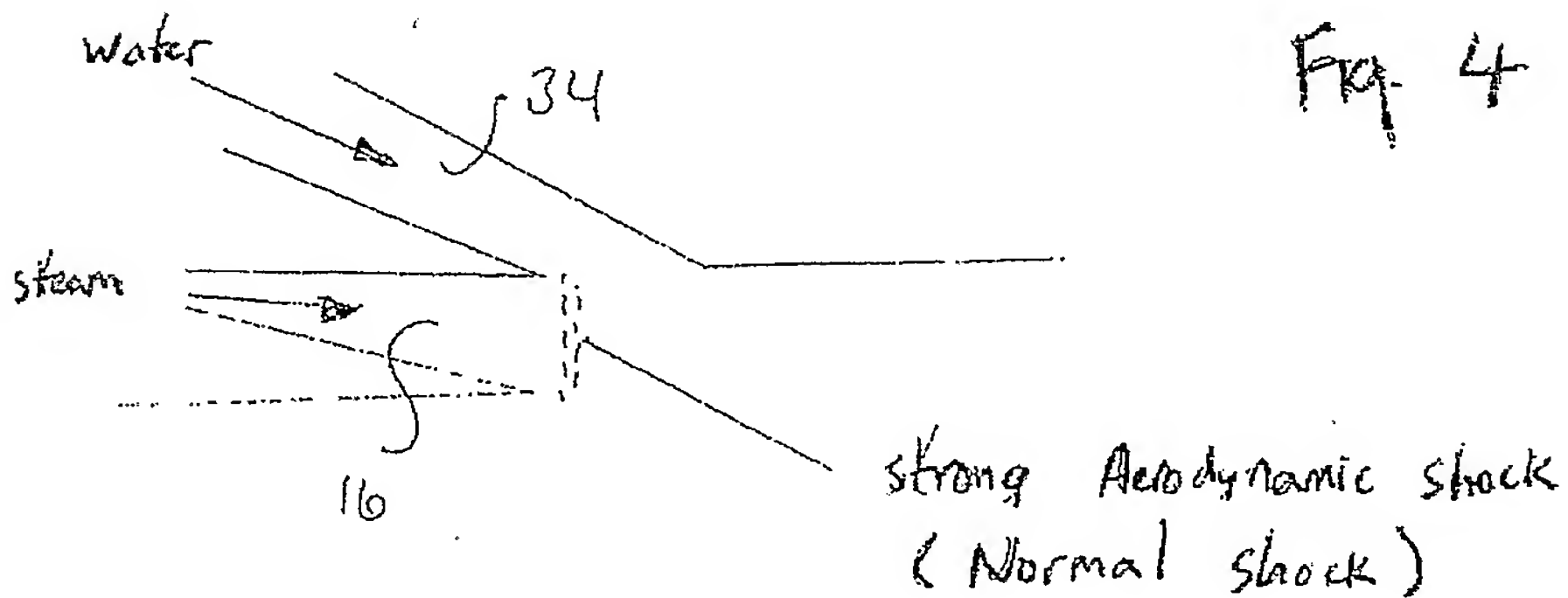
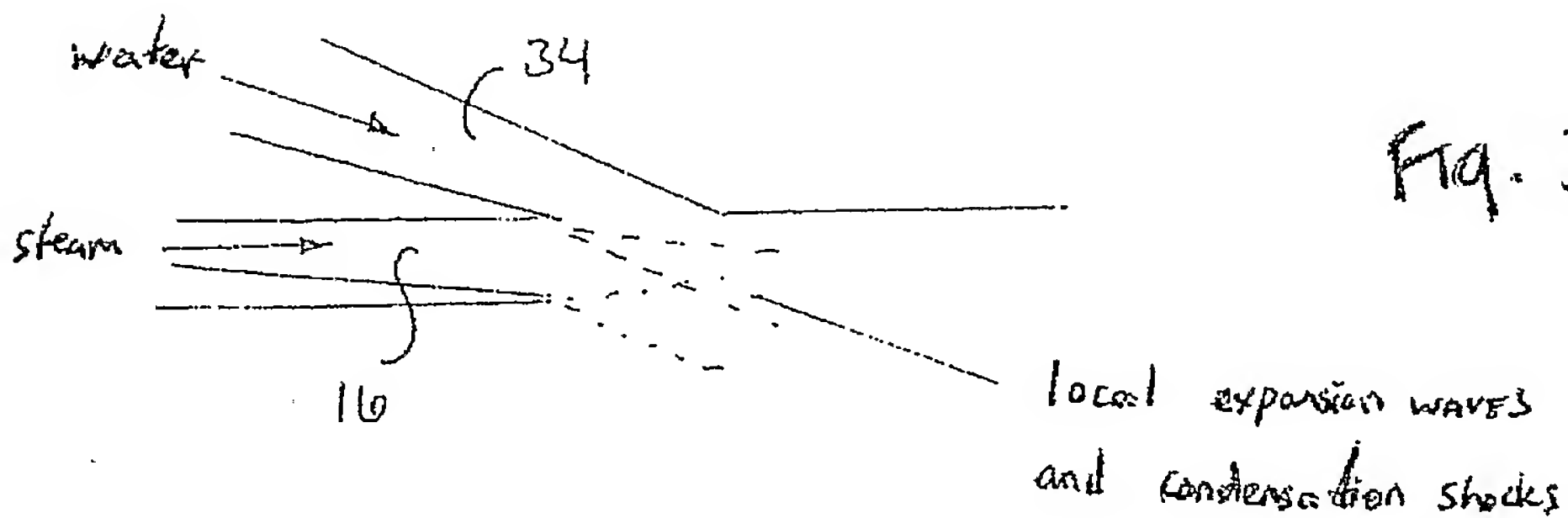
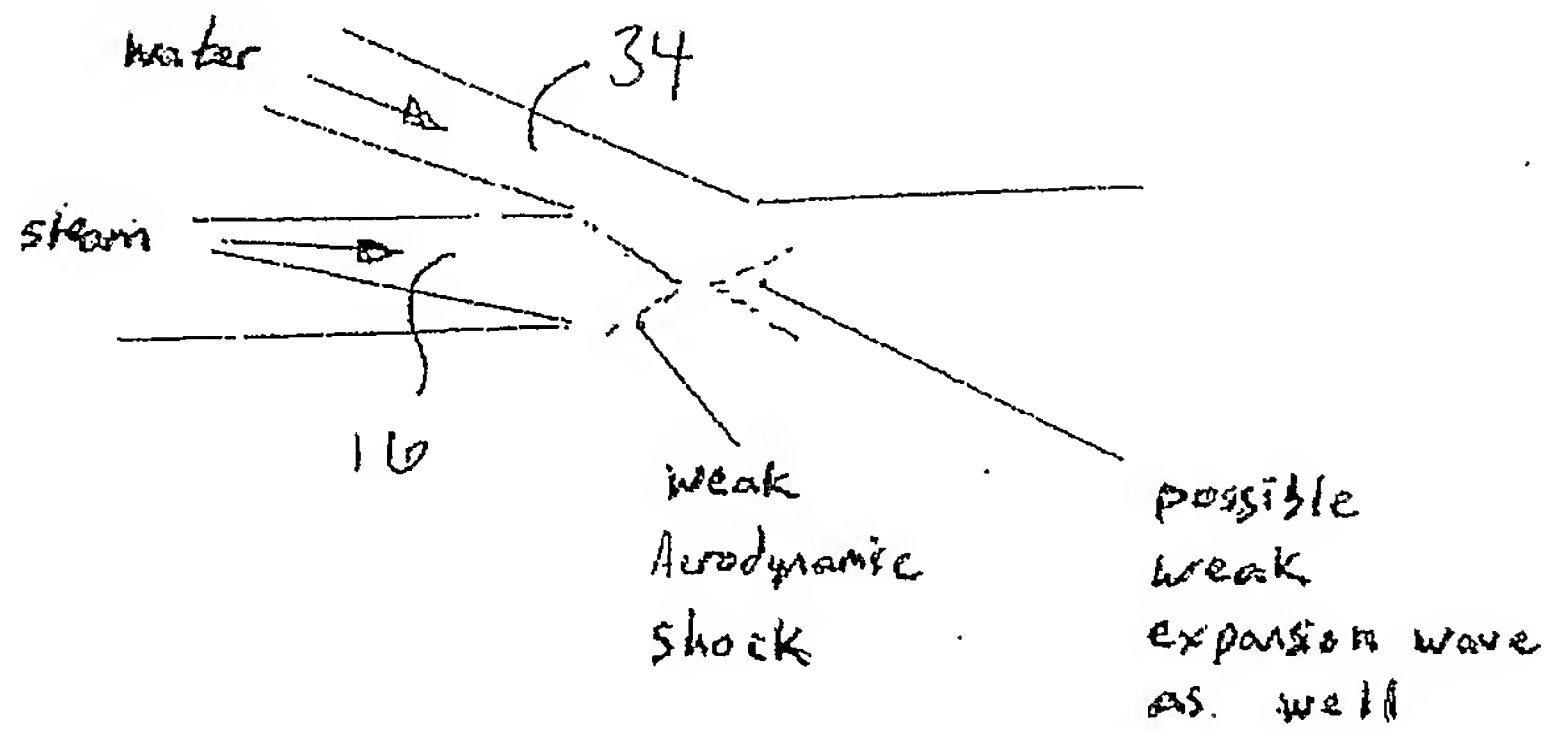
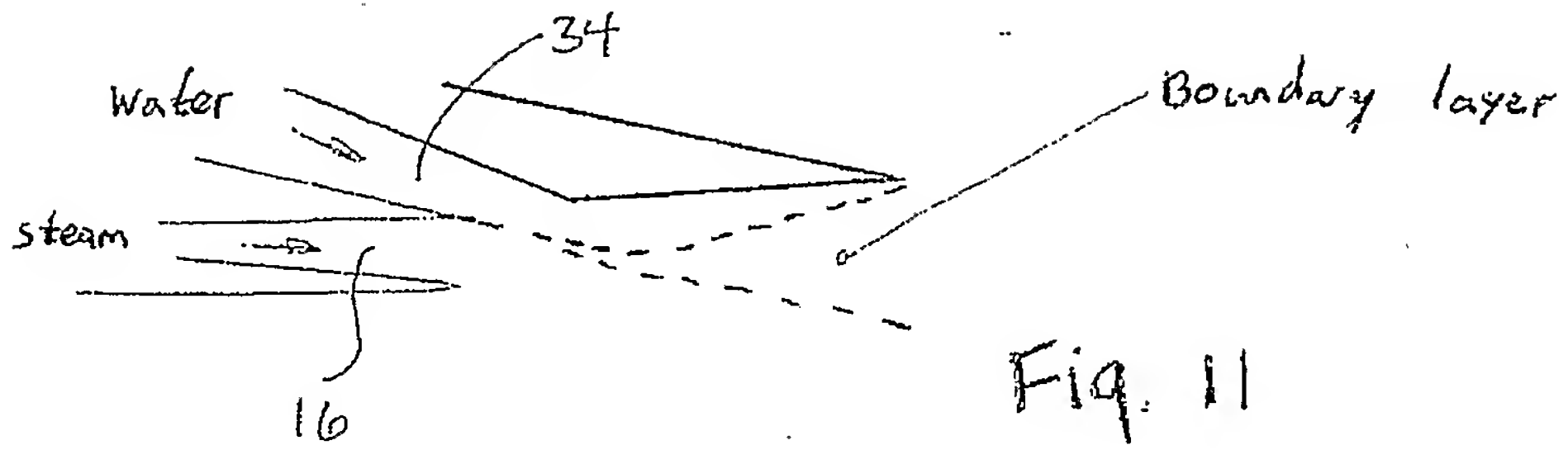


FIGURE 1







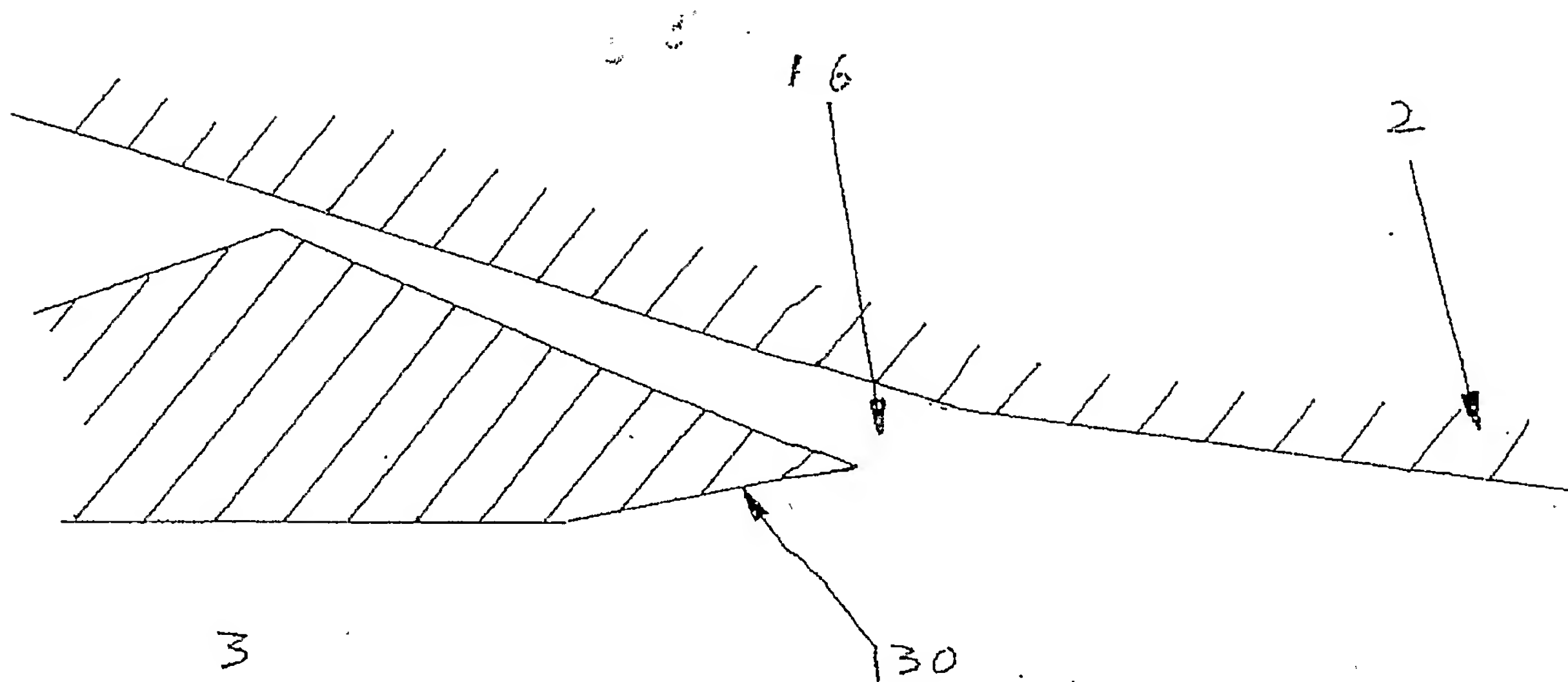


figure 5

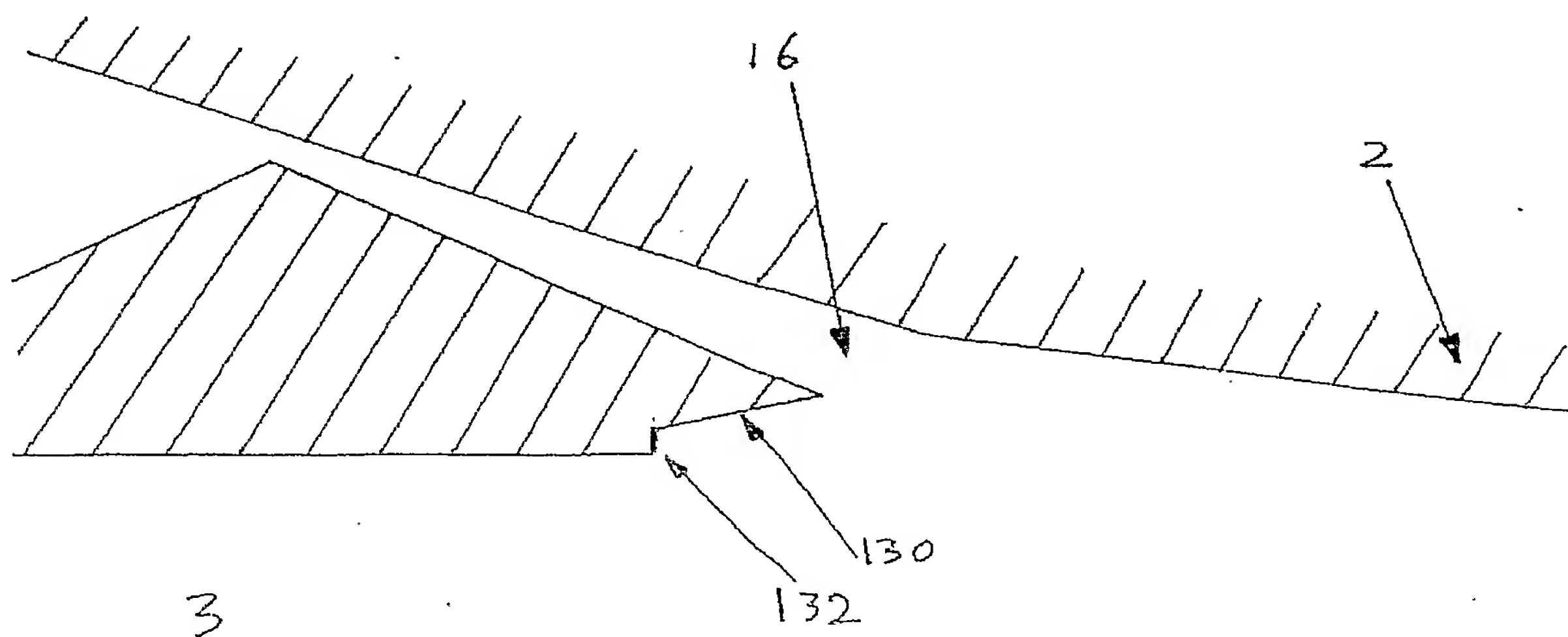


figure 6

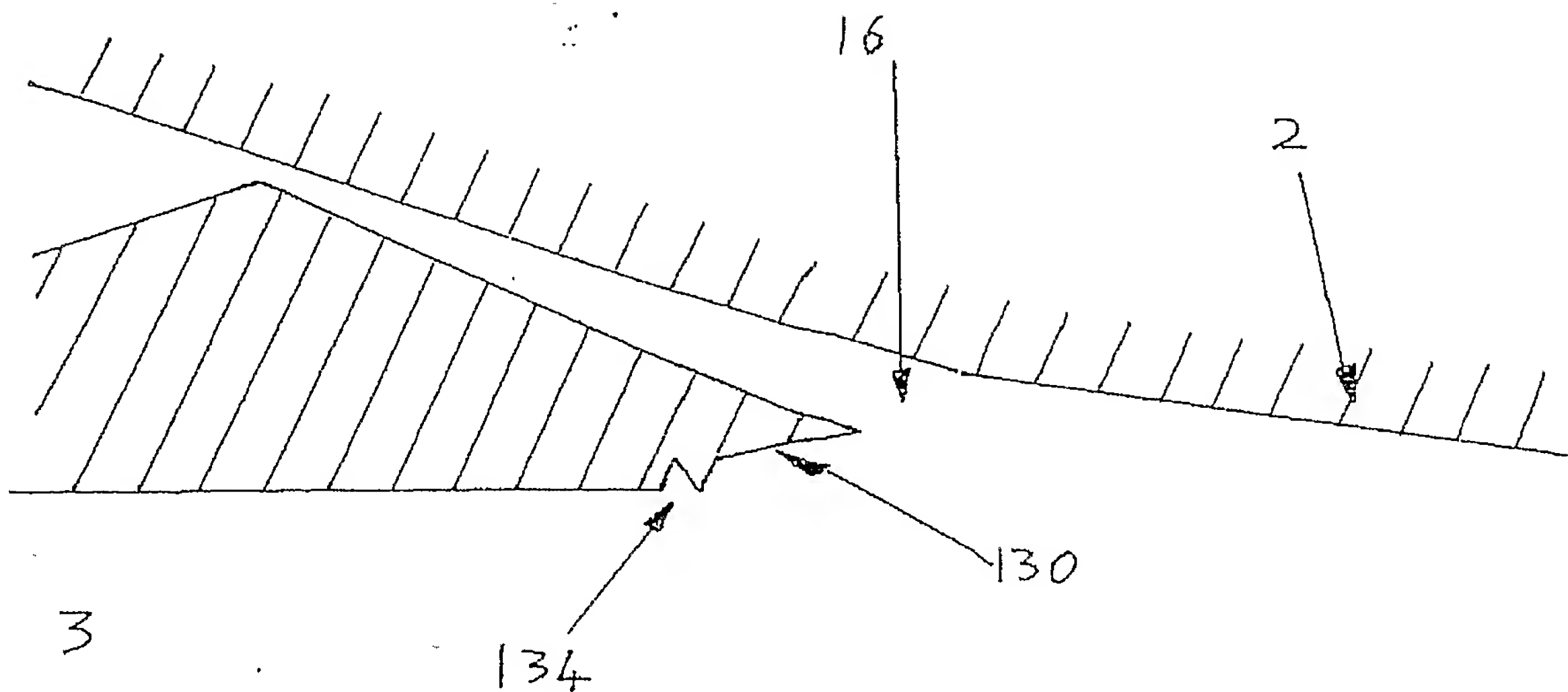


figure 7

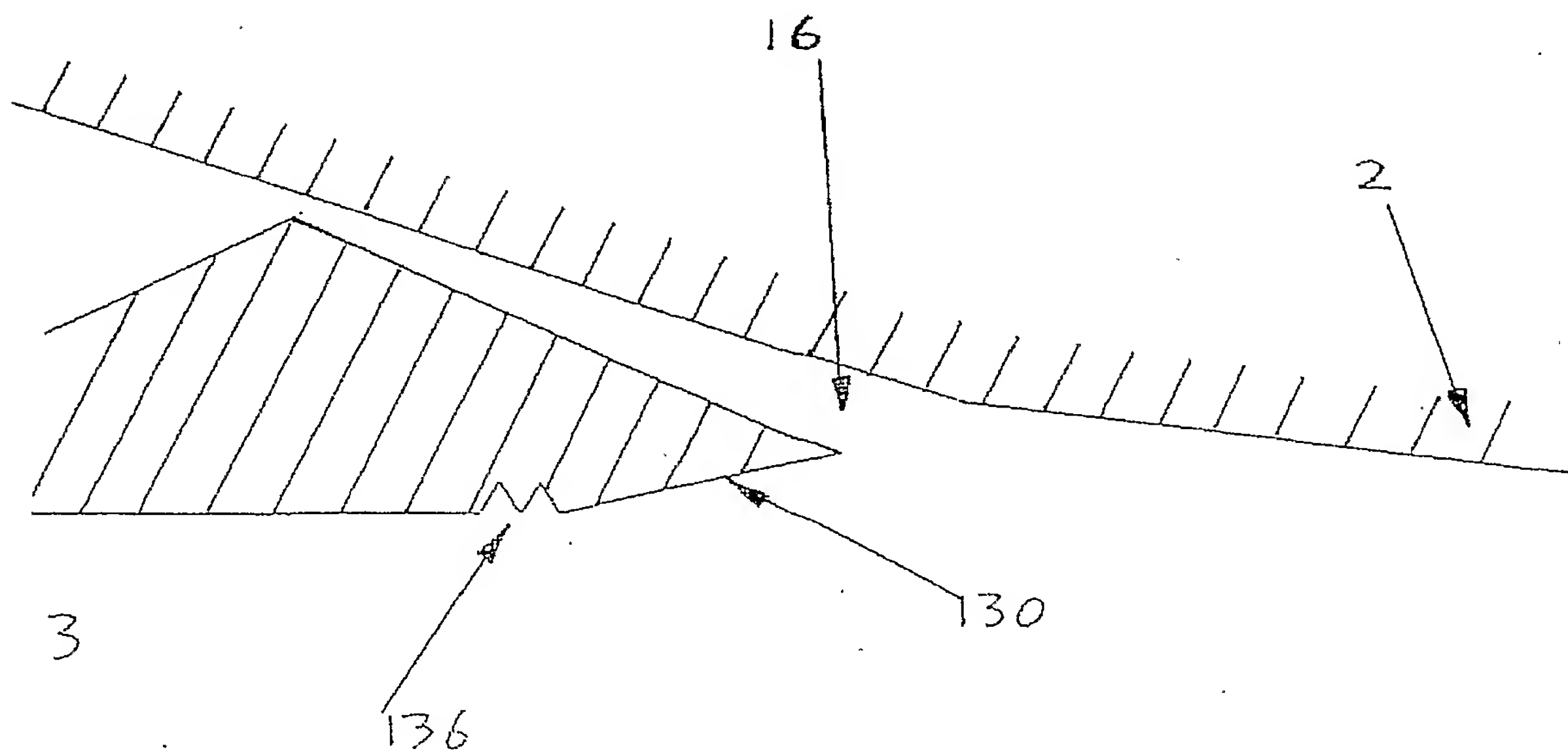


figure 8

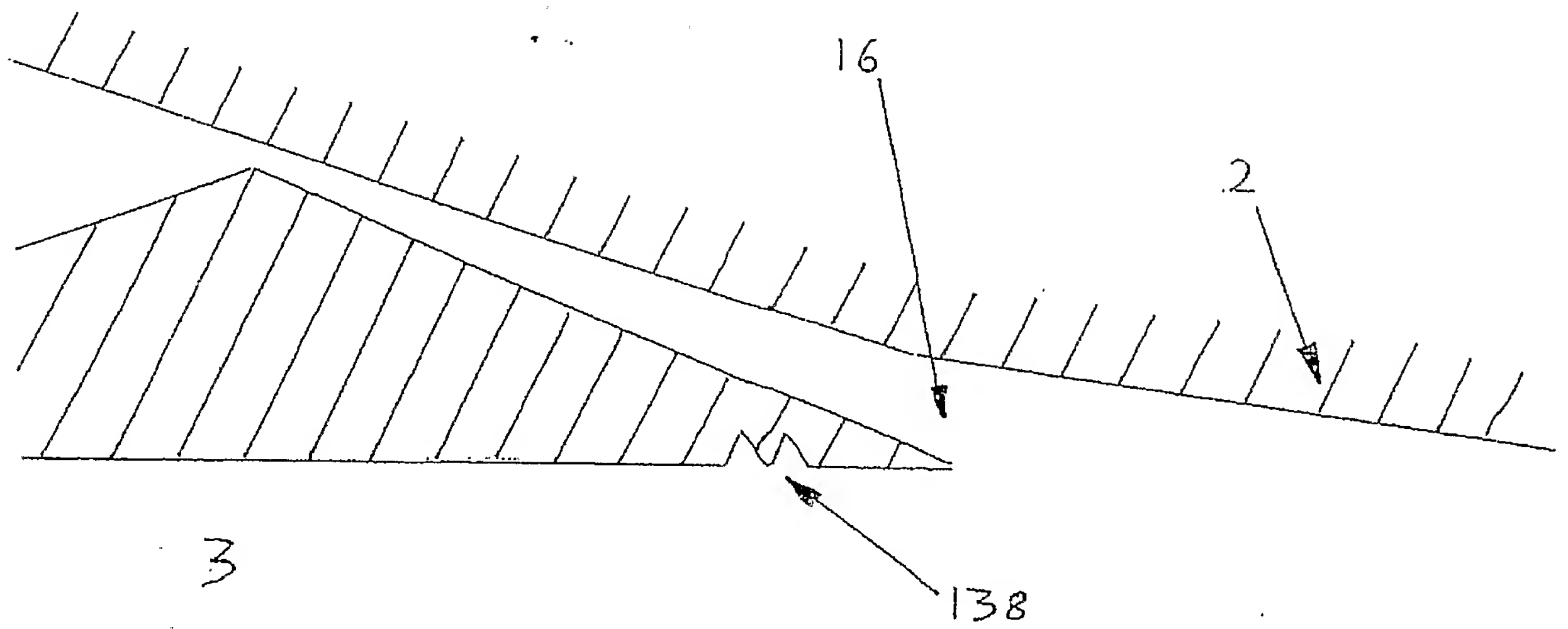


figure 9

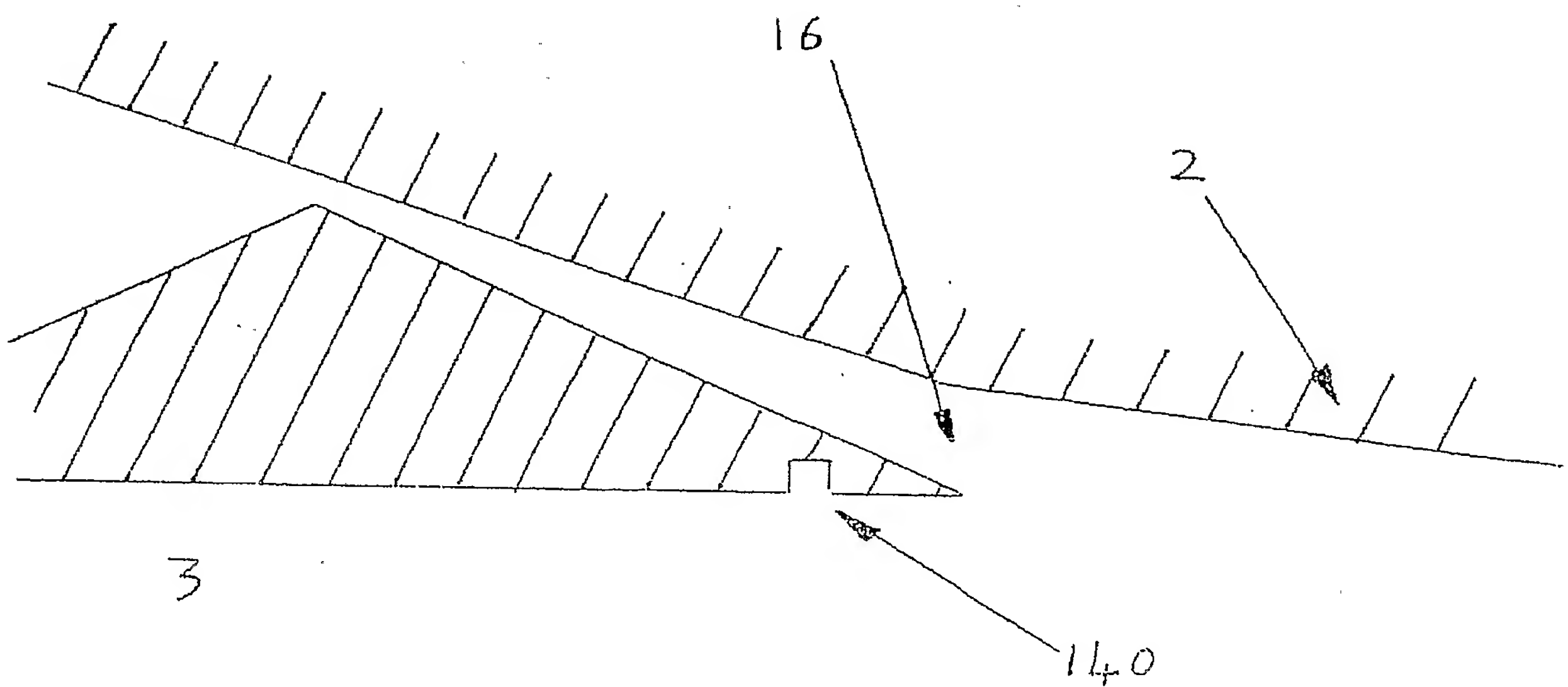


figure 10



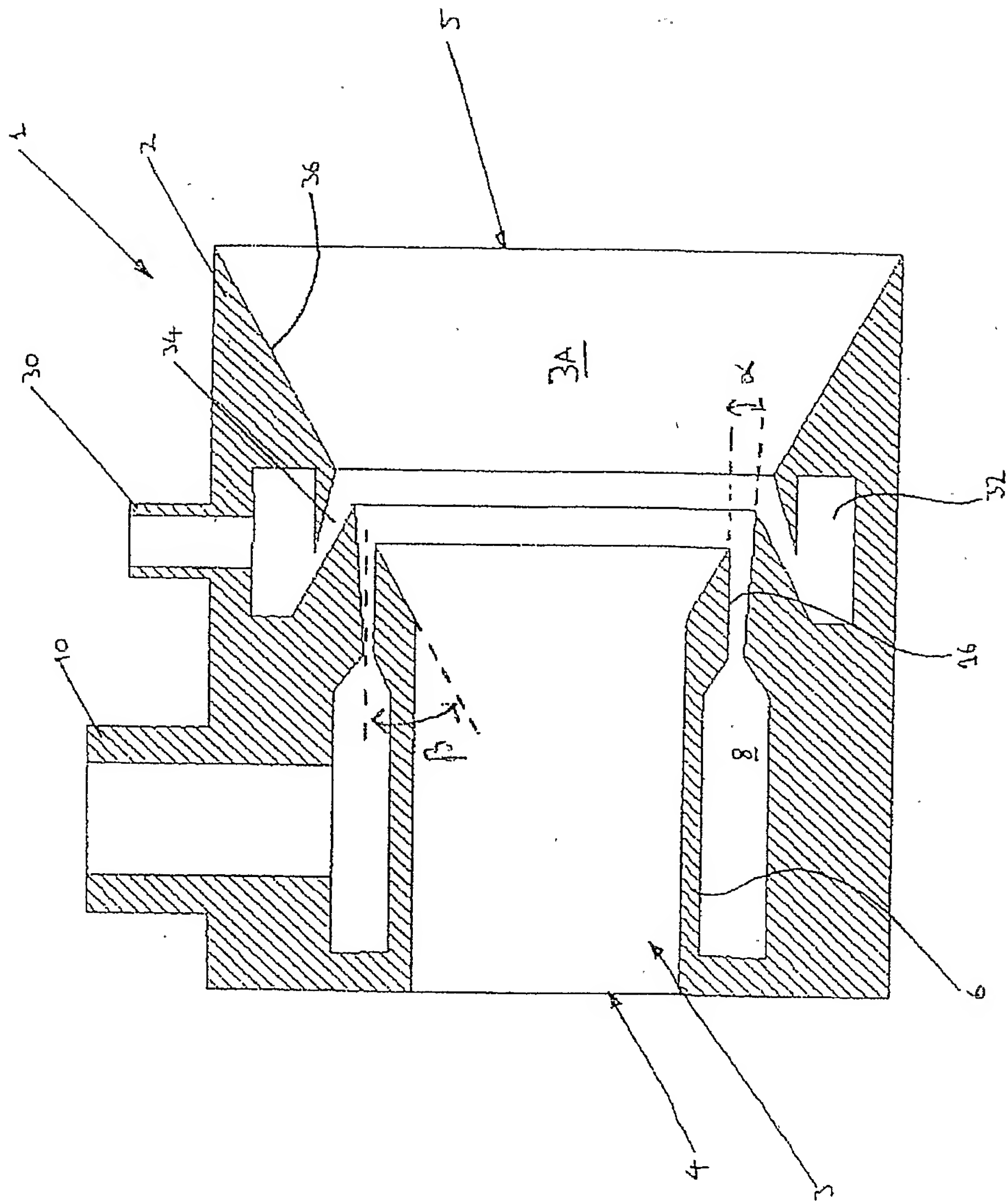
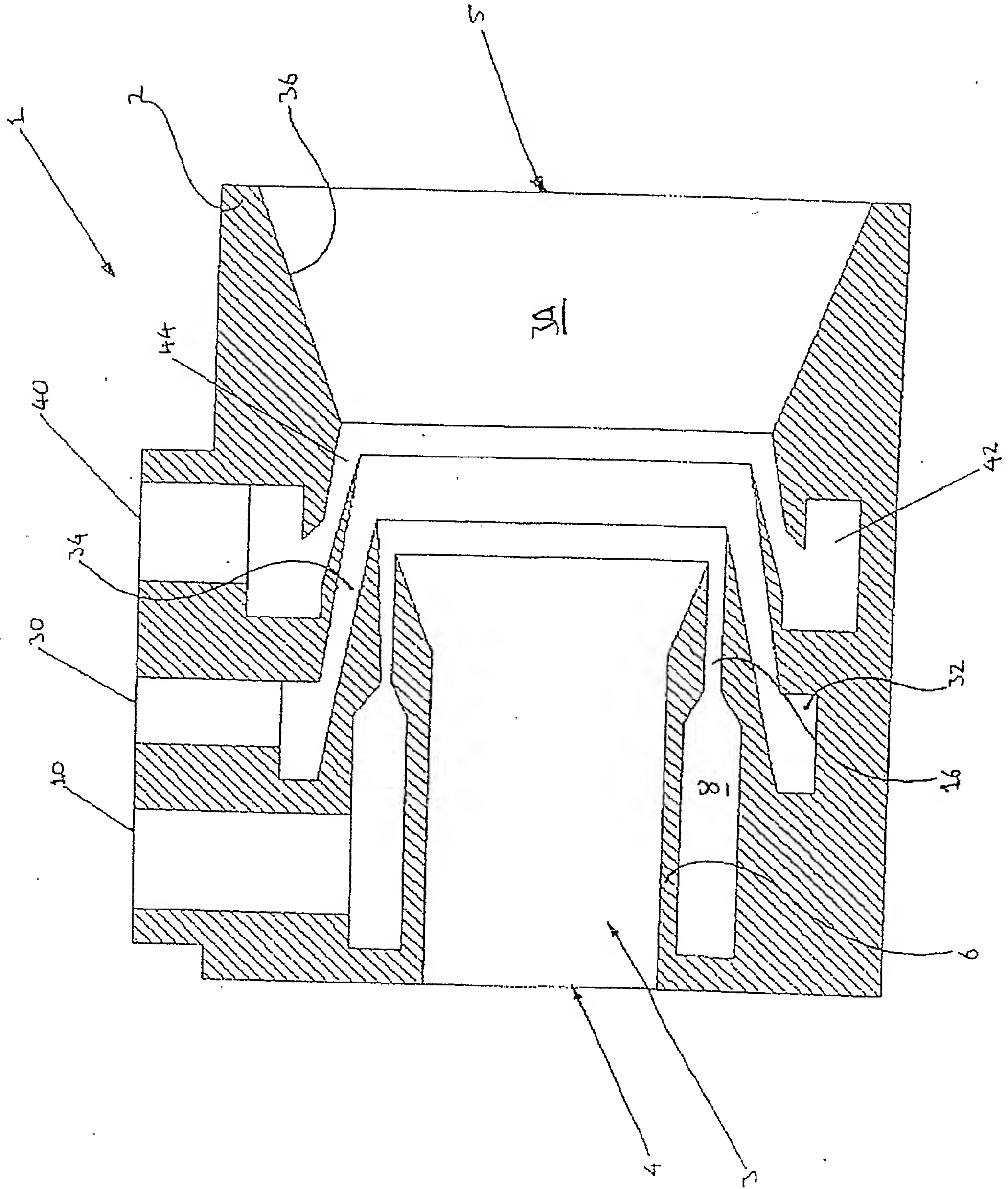
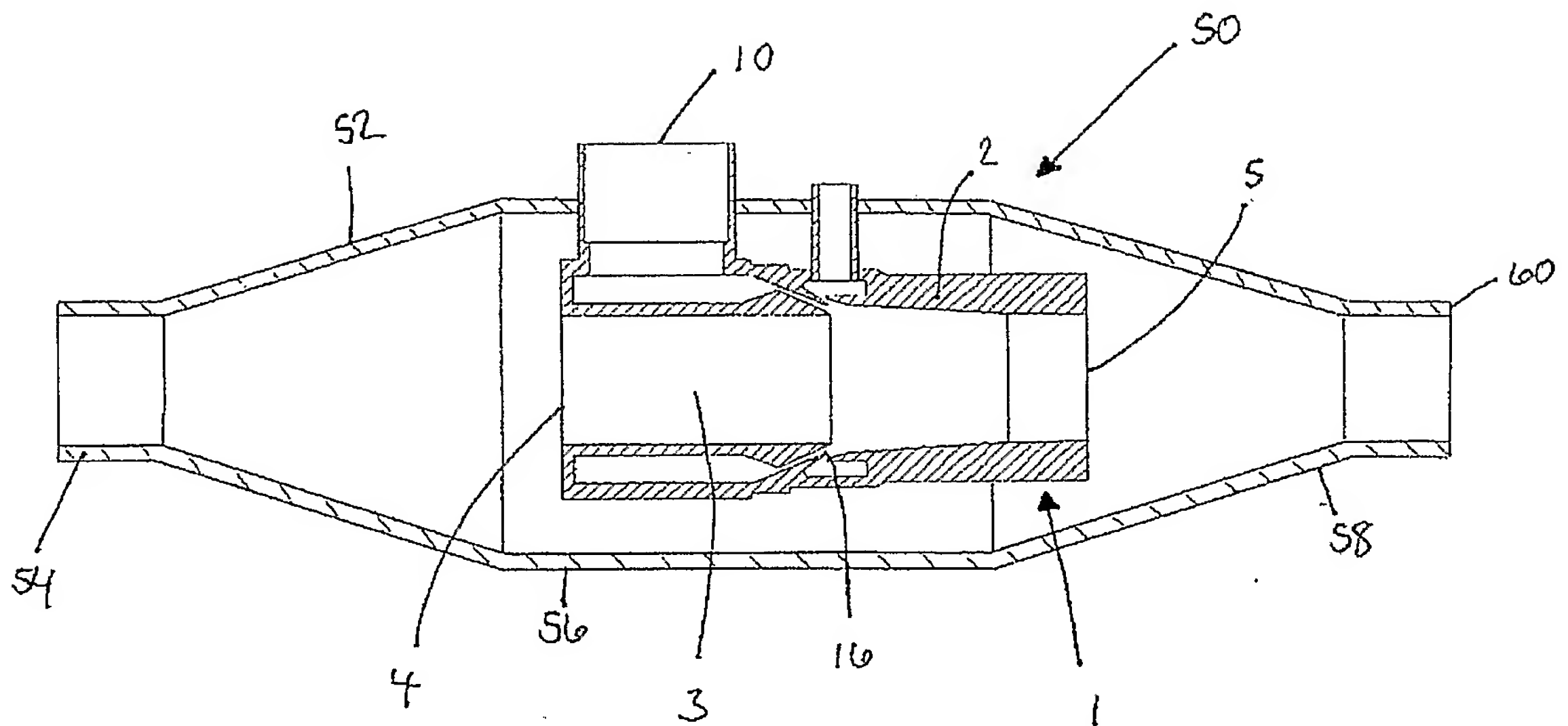


FIGURE 12









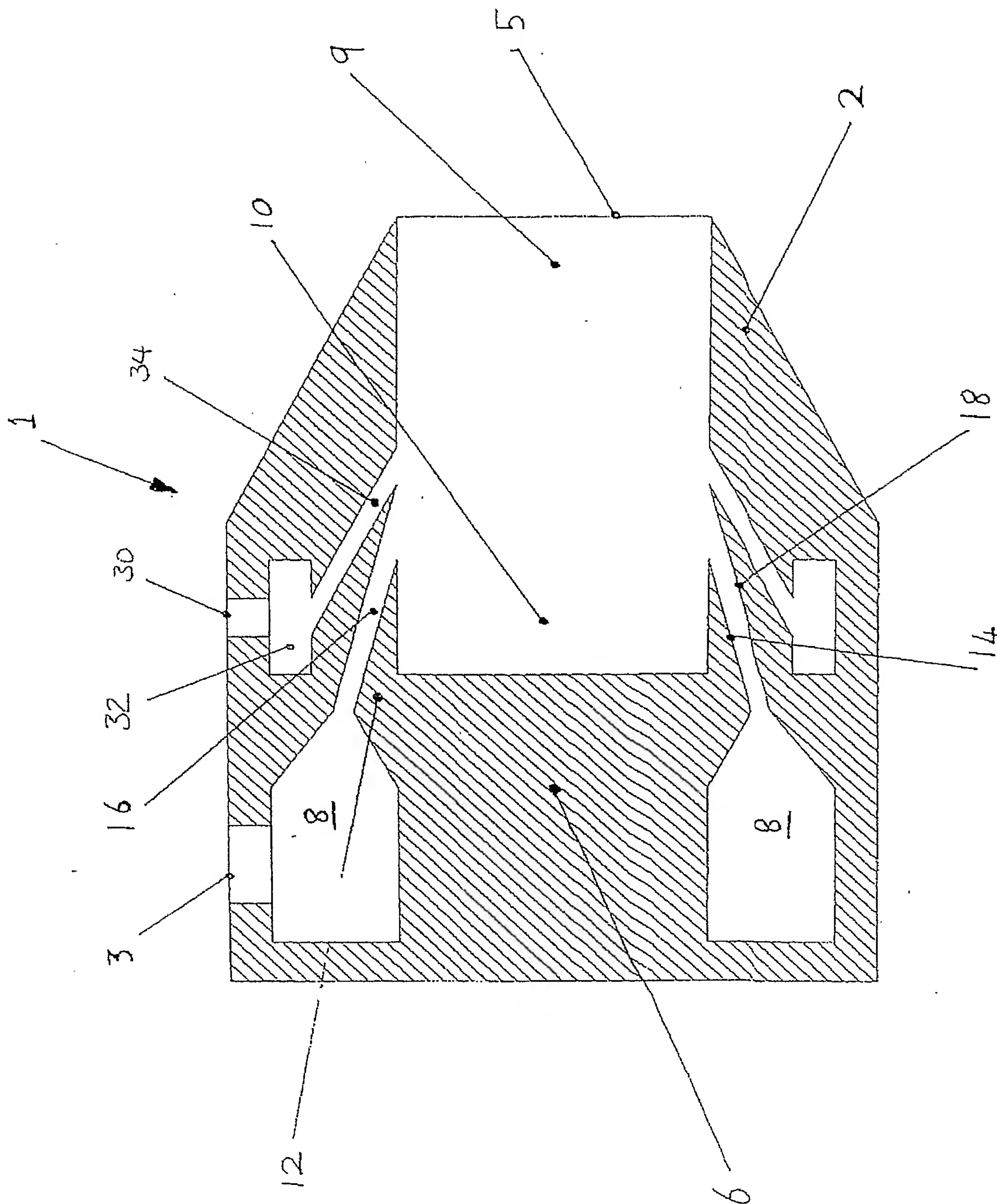


FIGURE 15



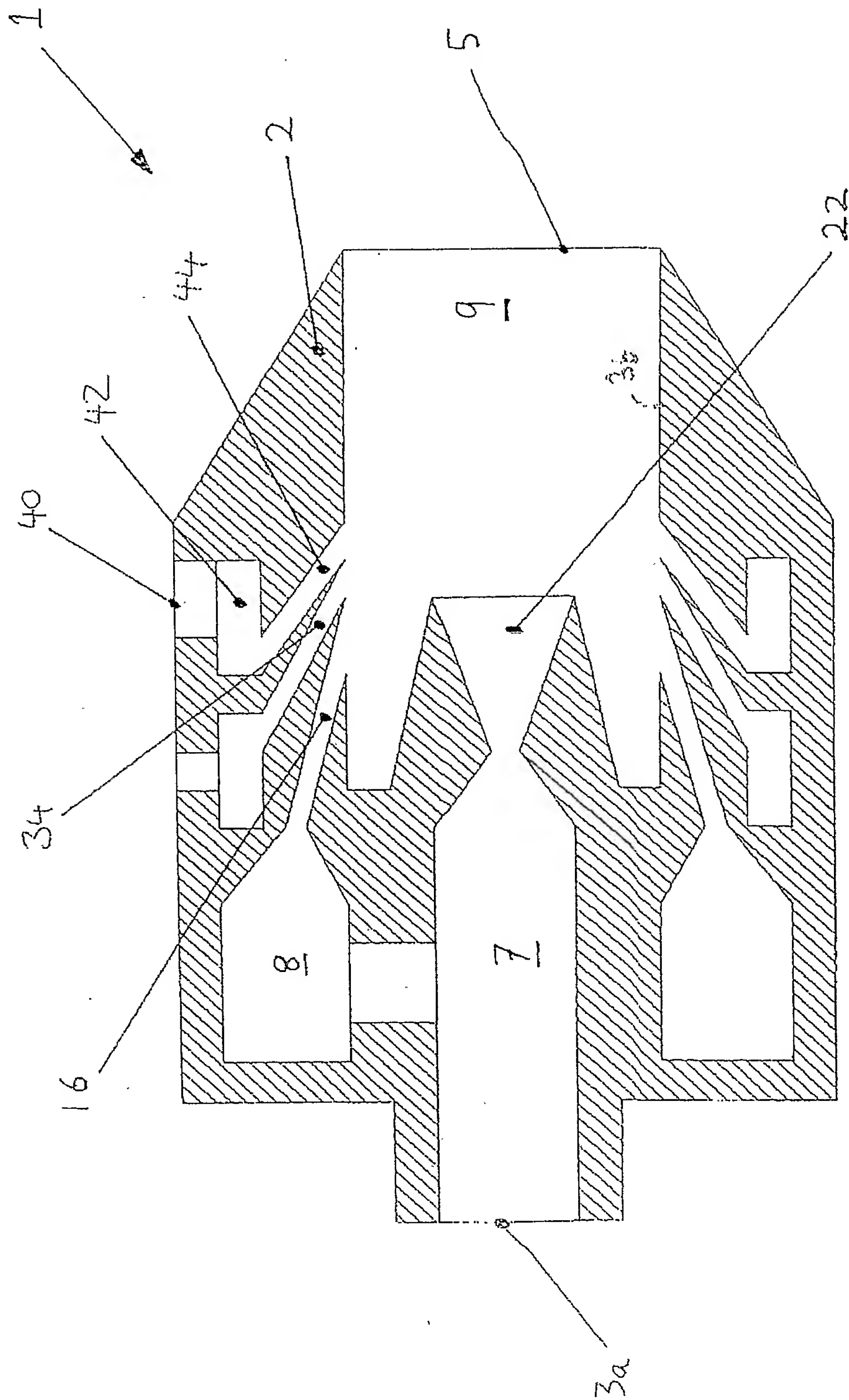


FIGURE 17

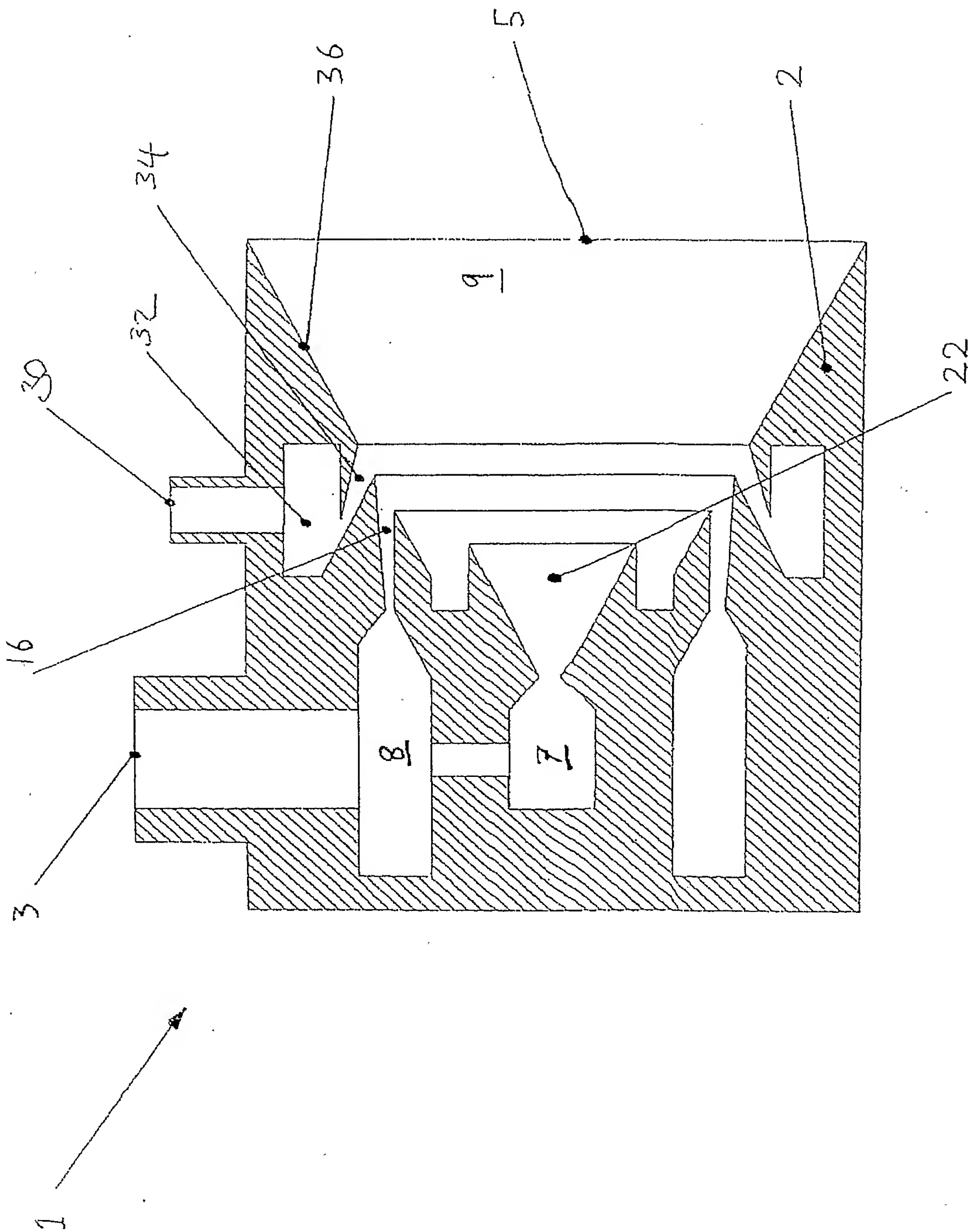
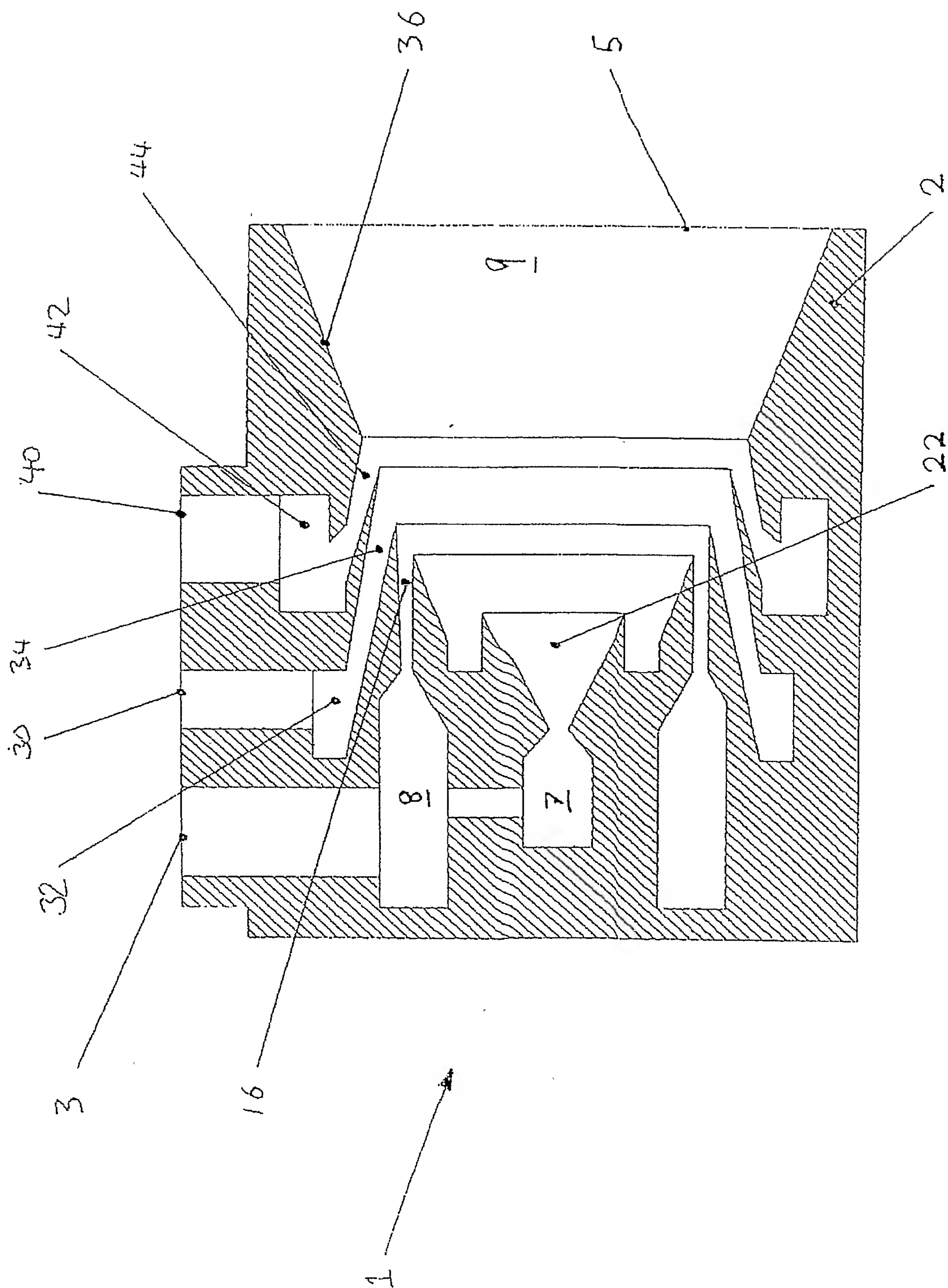


FIGURE 18







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